The Thesis committee for Benjamin Todd Carroll

certifies that this is the approved version of the following thesis:

Relevant Factors in the Path to

Successful Lean Transformation

APPROVED BY

SUPERVISING COMMITTEE:

Supervisor: _____

Kyle Lewis

_____

Erhan Kutanoglu

Relevant Factors in the Path to Successful Implementation of Lean

by

Benjamin Todd Carroll, BSME

Thesis

Presented to the Faculty of the Graduate School

of the University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Masters of Science in Engineering

The University of Texas at Austin

December 2011

Acknowledgements

First, I thank Jesus, my savior, who made this possible. Without you I would be lost.

I would like to thank my wife Lori for her unwavering support to me through this endeavor and to my boys for their patience through the many evenings away.

Thank you to my parents, Richard and Kae Carroll, for all of your encouragement and allowing me to believe I could do anything I set my mind to.

Thank you to Dr. Lewis for your guidance and patience through this thesis.

Thank you to Dr. Ambler and Dr. Nichols for giving of yourselves to allow such a great program to exist.

Thank you to my classmates of Cohort 21 who outclassed me in every way but were always so gracious.

Relevant Factors in the Path to

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by

Benjamin Todd Carroll, M.S.E.

The University of Texas at Austin, 2011

SUPERVISOR: Kyle Lewis

In any business environment companies experience challenges and competition. In this current worldwide economic crisis, the stakes are now higher. With every crisis comes opportunity. The best companies with the best methods and processes that create highest quality product for less money will have an extraordinary advantage over their less efficient, lower quality competition. The term 'Lean' describes how Toyota does business: fewer humans, less effort, less investment, fewer defects, less time to develop, less inventory. For companies that have truly understood and implemented these principles the effects are significant; but many others have failed Lean initiatives. What factors are necessary for a company to successfully adopt the processes proven by over 50 years of success in Toyota? Using both primary and secondary research, I compared attributes of four companies, three of which were successful, and one that did not make the conversion. Three main factors emerged, the **Technical Factor** -- knowing both your core business and having a deep understanding of Lean principles, the **Management Factor** -- strong leadership operating within Lean principles and with hands-on approach, and the **Human Factor** -- approaching the workforce with respect and employee engagement in problem-solving process. The following is a brief review of these factors and the tools and concepts that undergird them.

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1 Introduction

In light of the continuing global economic crisis at no time since the Great Depression has it been more imperative that the successful company strive for new ideas and possibly consider completely rethinking how business is conducted.

With every crisis comes opportunity. The best companies with the best methods and processes that create the most value for their customer in the most efficient and cost effective ways have an extraordinary advantage over their less efficient, lower quality competition. *Lean*, a term coined by John Krafcik, a researcher who helped write The Machine that Changed the World, describes how Toyota does business: fewer humans, less effort, less investment, fewer defects, less time to develop, and less inventory. For companies who have truly understood and incorporated these methods the effects are significant; however, for every story of a successful company increased in value and reduced waste as a result of adopting Lean, many others exist with failed Lean initiatives. In fact, a survey done in 2008 of 184 companies attempting to implement Lean related initiatives, 80% said their efforts are failing to achieve expected results (Peter Guarraia, 2008).

1.1 Problem Statement

How it is that so few companies can mirror Toyota's demonstrated success even while Toyota's leadership promotes the dissemination of their philosophies? What factors are necessary for a company to successfully achieve the levels of efficiency, reliability, and cost per unit that Toyota has achieved through processes proven by over 50 years of success at Toyota?

1.2 Application

Today's economic environment leaves no room for laggards. Being a manager and leader of engineers in a product development company, or even service industry, it is ever more important to be knowledgeable of the very best methodologies and processes to bring products from inception through to steady and profitable production. More

companies around the world, whether in the automotive industry, military, oil and gas, other industries, are even now striving to increase efficiency and quality through adoption of better design and manufacturing processes. On a larger scale, the economic wellbeing of the U.S. may be at stake if we as a nation cannot maintain competitiveness in the world economy.

1.3 Scope

This thesis is intended to create a foundation for the company leader who wants to transform his or her business to maximize customer value and eliminate waste and unnecessary expense. To do this I provide a brief overview of Lean principles and describe three separate and distinct areas, or 'factors,' where Lean can be applied. I then present research that shows how a company must incorporate all three factors together synergistically to enable significant improvement to occur.

2 Literature Review

2.1 Genesis of the Study of Lean

The western study of Lean has its roots in the ground breaking study by a group from MIT led by Jim Womack, Daniel Jones and Daniel Roos. In 1985 Japan's auto imports were cutting substantially into the US market share. Indeed, between 1960 and 1985 the US traded no less than 50% of its worldwide market share to Japan (Womack, Jones, Roos, 1990 and 2007). To try and understand what was happening, Massachusetts Institute of Technology (MIT) initiated a program called the International Motor Vehicle Program (IMVP) aimed at researching the secrets behind the Japanese success and to directly examine the disparities between Japanese and Western automotive production capabilities. The result was the publication The Machine that Changed the World. Lean production, used by Toyota, was fundamentally different in approach and execution to production. Table 1 shows a

Table 1: Japanese vs. American Product Development, mid 1980s

	Japan	US
Average Engineering hours per new car (millions)	1.7	3.1
Average development time per new car (months)	46.2	60.4
Number of employees per Project Team	485	903
Supplier share of Engineering	51%	14%
Engineering Change Cost as percentage of total steel stamping die costs	10% to 20%	30% to 50%
Ratio of delayed products to on time products	1 in 6	1 in 2
Prototype Lead Time (months)	6.2	12.4
Return to Normal Quality after New Model (Months)	1.4	11

summary of stark differences in product development performance between Japanese producers and American producers. US producers include Ford, GM, and Chrysler. Japanese producers include Nissan and Honda. Although Toyota was decidedly ahead of its own national competitors with respect to Lean, the differences are still quite clear (Womack, Jones, Roos, 1990 and 2007).

With the data to prove that Toyota was able to build high quality cars for less cost through their unique processes, authors and researchers began to examine more carefully what these processes were and how they differed from the modern mass production methods and philosophies perfected by companies like General Motors and Ford. The research was also aimed at trying to understand how these processes might be applied to these American auto companies and even to other industries. A number of titles embody these studies including Lean Thinking, by Jim Womack and Daniel Jones, and Toyota Way by Jeffrey Liker. To provide context regarding Lean and mass production philosophies, a few of the historically significant turning points are covered below.

2.2 Craft Manufacturing

Prior to WWI, the only way products were developed and made was by skilled craftsmen. Craft production essentially relied on skilled craftsmen taking design objectives from each customer, designing, and building each item as a single prototype. A clockmaker, for instance, would be responsible for the initial design, procurement of materials, forming and machining, assembly, and test. Even the few automobile producers of that time built their cars exclusively by the craft method. Each part was made uniquely and filed, cut and polished to fit with other parts. No two automobiles were the same (Womack, Jones, Roos, 1990 and 2007).

2.3 Mass Production

In the interim between WWI and WWII, Henry Ford initiated a revolution in manufacturing with his assembly line approach at his Highland Park facility in Detroit. It was actually the use of standard gages and the ability to produce interchangeable

parts, a concept commonly attributed to Eli Whitney in combination with the continuous assembly line that provided the foundation for automated production and ushered in the Model T and an era of *Mass Production* (Hounshell, 1984).

Mass production relies on making enormous numbers of the same thing over and over again to make use of efficiencies gained through elimination of change-overs and quantity purchasing. While this approach was far superior to the custom manufacturing methods it replaced, mass production was not conducive to specific customer needs or wants. As Henry Ford was famous for saying, *Any customer can have a car painted any color that he wants so long as it is black* (Ford, 2011).

2.4 Deming's 14 Points

A new model began emerging in the mid 20th century. In 1950, to help restore Japan after World War II, American occupation forces sent in the Economic and Scientific Section (ESS) group to help with the rebuilding of Japanese industry. Dr. William Edwards Deming was brought in as part of this group.

Deming was himself a student and developer of efficient methods of development and manufacturing. He studied Henry Ford and other early efficiency and innovation scholars. Through his studies Deming codified his famous 14 points during his early efforts with the Japanese (Deming, 1982). The 14 points are high level and refer to the whole process.

1. Create constancy of purpose for improvement of product and service with the aim to become competitive and to stay in business, and to keep providing jobs.
2. Adopt the new philosophy. We are in a new economic age. Western management must awaken to the challenge, must learn their responsibilities, and take on leadership for change.
3. Cease dependence on inspection to achieve quality. Eliminate the need for inspection on a mass basis by building quality into the product in the first place.

4. End the practice of awarding business on the basis of price tag. Instead, minimize total cost. Move toward a single supplier for any one item, on a long-term relationship of loyalty and trust.
5. Improve constantly and forever every process for planning, production and service. Improve quality and productivity, and thus constantly decrease costs. Quality must be built in at the design stage.
6. Institute training on the job. This should be a part of everybody's every day's activities.
7. Adopt and institute leadership. The job of management is not supervision, but leadership. The aim of supervision should be to help people and machines and gadgets to do a better job.
8. Drive out fear so that everyone may work effectively for the company because they want it to succeed.
9. Break down barriers between staff areas or departments. People in research, design, sales, and production must work as a team, to foresee problems of production and in use that may be encountered with the product or service.
10. Eliminate slogans, exhortations and targets for the workforce asking for zero defects and new levels of productivity. Such exhortations only create adversarial relationships, as the bulk of the causes of low quality and low productivity belong to the system and thus lie beyond the power of the work force.
11. Eliminate numerical quotas for the workforce and numerical goals for management. Quotas are the wrong focus and do one of two things – either the quota is too high and quality suffers, or the quota is too low and efficiency suffers. Provide the best tools and processes and allow the employee to work up to their own potential. If the result is poor, then the system must be examined, the employee needs better training, or it is not the right fit for that employee.
12. Remove barriers that rob people of pride of workmanship.

13. Institute a vigorous program of education and self-improvement for everyone. Let them participate to choose the areas of development.

14. Put everybody in the company to work to accomplish the transformation.

Anyone engaged in the business of developing and manufacturing products should recognize that the above list alone has the power to transform their business if truly followed. Sadly, Deming was all but ignored by most modern industry within the US and around the world except for a very few within the faltering post WWII Japanese economy (Deming, 1982).

Deming instilled these methods into the heart of a number of Japanese business owners including Kiichiro Toyoda, and Eiji Toyoda. Deming's influence combined with Japan's national crisis and Kiichiro Toyoda single minded application was the primary genesis of much of the modern Lean revolution. Eiji Toyoda, Kiichiro's successor, continued using Deming's points as a launching platform for the Toyota Motor Company, honing and improving the philosophy. Taiichi Ohno, employed by Eiji, formulated the Toyota Production System (TPS) to create what Jeffrey Liker coined the *Toyota Way*. This was the origin of Lean philosophy that was eventually applied to the entire product development process (Womack, Jones, Roos, 1990 and 2007) (Womack, Jones, Roos, 1990 and 2007). These Lean principles are codified in Toyota's updated 14 principles below (Liker, 2004).

2.5 Toyota's 14 Principles

1. Base your management decisions on a long-term philosophy, even at the expense of short-term financial goals.
2. Create a continuous process flow to bring problems to the surface.
3. Use the *pull* systems to avoid overproduction.
4. Level out the workload (*heijunka*). (Work like the tortoise, not the hare.)
5. Build a culture of stopping to fix problems, to get quality right the first time.

6. Standardized tasks and processes are the foundation for continuous improvement and employee empowerment.
7. Use visual control so no problems are hidden.
8. Use only reliable, thoroughly tested technology that serves your people and processes.
9. Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.
10. Develop exceptional people and teams who follow your company's philosophy.
11. Respect your extended network of partners and suppliers by challenging them and helping them improve.
12. Go and see for yourself to thoroughly understand the situation (*genchi genbutsu*).
13. Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.
14. Become a learning organization through relentless reflection (*hansei*) and continuous improvement (*kaizen*).

From the late 1970's through the 1980's American auto manufacturers saw a steady decline in market shares as Japanese automobiles began making in-roads into the U.S (Womack, Jones, Roos, 1990 and 2007). So pervasive was this second *Japanese invasion* that the government invoked *Voluntary Trade Restrictions* on Japanese imports in 1981. This limited the total number of vehicles from Japan to 1.68 million vehicles annually. This cap was eventually raised and then lifted altogether in 1994 (Benjamin, 1999). The bottom line: quality and cost of ownership of American cars could simply not compete.

During this time, despite trade restrictions, Toyota Motor Company established itself as the gold standard for development and implementation of Lean philosophy.

2.6 The Lean Enigma

Innumerable books, journal articles, and websites provide detailed information on Lean methods for elimination of waste and creating value in an organization. Thousands of senior business leaders have toured Toyota facilities to see for themselves the marvel of a Lean enterprise (Fine, Hansen, Roggenhofer, 2008). What they saw was apparently a very simple concept: simply eliminate as much waste as possible and focus on customer value. In practice, some surveys show that the majority of Lean initiatives are often unsuccessful even after costly earnest effort (Peter Guarraia, 2008); however, there is reason to be encouraged. There are three factors common to those companies I have researched who have been successful in transitioning their companies from inefficiency and waste through to continual effective utilization of Lean principles.

2.7 Three Critical Factors plus One

These three factors are the Management Factor, the Technical Factor, and the Human Factor. A fourth factor, Crisis, is recognized and described briefly below as well. There are three primary entities in any business: 1) the thing that provides value to customers, 2) management, and 3) the employees. Customers purchase cars because the value the car brings to them. Management provides the essential role of governance and direction for a company. Nothing can happen, of course, without the employees at every level of a company. My research indicates that companies who have successfully implemented Lean philosophy have applied it to all three of these business areas simultaneously (see Figure 1). I will provide a summary of this research below.

2.7.1 The Management Factor

The idea of *Lean Management* has developed out of an evolving and ever expanding concept of how to apply Lean principles. Lack of understanding by company leadership can stop a Lean conversion dead in its tracks. Even if a fairly high level manager tries to fully embrace Lean, resistance at the Vice President or CEO level may occur. For instance, during the time that a company is attempting to implement Lean

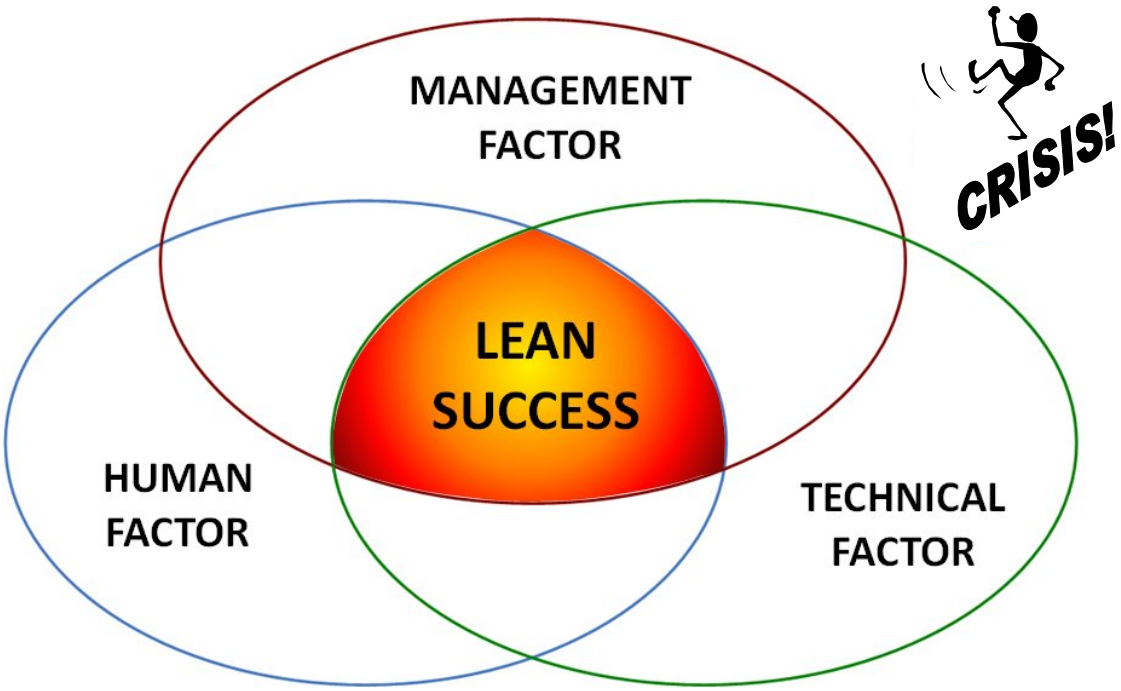

Figure 1: Lean Factor Synergy

principles, difficulties in making customer orders can arise as production flow is shifted and new systems are being created. Further, the balance sheet can be affected adversely by both bobbles in the learning curve as well as a phenomenon where falling levels of inventory appear as loss on the modern accounting balance sheet even though it does not necessarily represent value if the inventory cannot be sold to a future buyer. Hands-on guidance, passion for the vision, empowerment, and patience are all hallmarks of a Lean Leader (Womack J. P., 1996).

This factor can be best summarized in a comparison between the traditional management philosophy and leadership demonstrated by those who have adopted Lean principles.

2.7.1.1 *Modern Management vs. Lean Leadership*

Traditional management is highly layered and departmentalized. Each employee has their own responsibilities, career, and boss to serve. This structure, shown in Figure 2 can be traced back to Fredrick Taylor's early examination of organizational structure

(Taylor, 1911 and 2007). This structure tends to focus inward, create departmental walls, and can cause the focus of the customer and the value stream to become diluted.

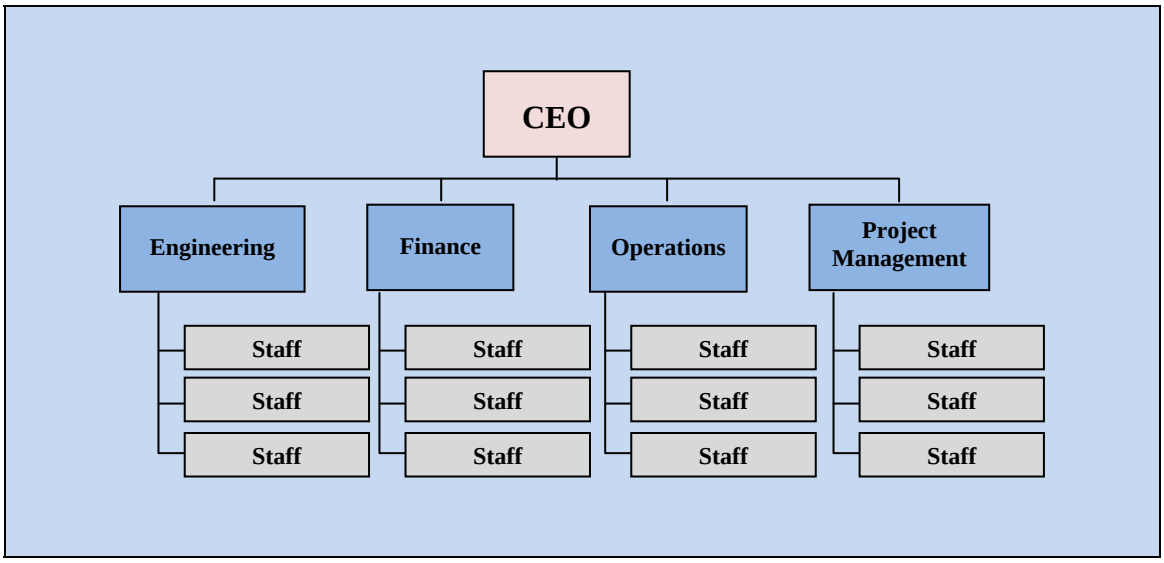

Figure 2: Functional Management Structure

Handoffs between department silos can rob individuals of the ability to see the whole value stream. Individuals tend to focus on their own area often at the expense of others down the line. An alternative structure, called a *horizontal* structure, flattens out the hierarchy with the intent to allow for better visibility of product flow and value creation (Womack, 2011). This structure has been used successfully by Wiremold, one of the case study companies discussed below.

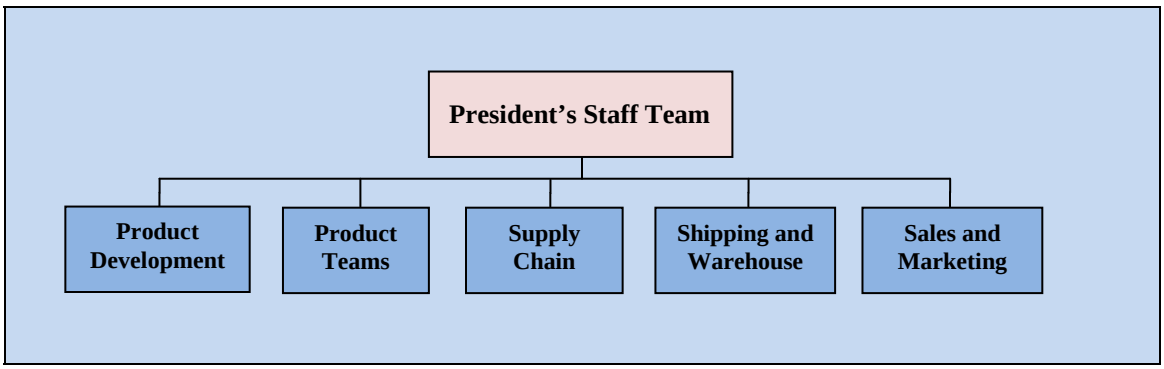

Figure 3: Horizontal Management Structure

In an apparent contradiction Toyota management organization is also very hierarchical and structured (Osono, Shimizu, Takcuchik, Dorton, 2008). The difference is that employees are trained to see the value stream and encouraged to be problem solvers and enabled to improve their own work processes through Lean leadership techniques. So, while horizontal management structure may help some companies see the value stream, difficulty with a functional management structure can be overcome through education and training.

Table 2 on the following page summarizes the key differences between traditional *Modern Management* and *Lean Leadership* that are fully elaborated in Gemba Walks under Modern Management vs. Lean Management (Womack, 2011).

2.7.1.2 ***The Lean Conversion- Radical Change then Incremental Change***

Significant improvement in business processes, quality, and value require *kaikaku*, or radical change, initially. Timid leaders may try to apply *kaizen* where *kaikaku* is required dooming the operation from the beginning. Piecemeal or temped inclusion of Lean principles will not make lasting change because the way business is conducted in a Lean enterprise requires methods that are very different from traditional management techniques. Leadership must be willing to make difficult decisions up front in order to establish a foundation from which a deep understanding and implementation of Lean principles can grow.

Difficult early decisions should include consideration of significant headcount reductions as necessary if headcount cannot be justified. Next, significant restructuring of manufacturing should be implemented as soon as possible. The supply chain and vendor selection will likely need to be reduced to those who can work with you as reliable team members. They are a critical piece of the flow. Finally, all other parts of the business including Product Development must be evaluated for wasteful processes and low value projects and activities. For lasting impact, Lean must stretch from senior management to the last employee on the production line (Shook, 2003).

Table 2: Modern Management vs. Lean Leadership

Modern Management	vs.	Lean Leadership
Authority	**vs.**	**Responsibility**
Seek authority before taking action.		Lead as if no authority exists through problem solving (see A3).
Results	**vs.**	**Process**
Judging success based on results (Includes, QC inspection, annual reviews, large final design reviews).		Ensure success by managing the process. Trace issues all the way to the source immediately. Address performance issues proactively through teaching, coaching and asking question.
Give Answers	**vs.**	**Ask Questions**
Feeling compelled to have and give all the answers. Rely little on employee input.		Foster thinking and problem solving through asking questions (5 whys)[i].
Plans	**vs.**	**Experiments**
Creating grand plans that inevitably miss unforeseen issues and factors.		Each plan is treated like an experiment where it is understood that the outcome is unknown, and whether failure or success, something is learned.
Formal Education	**vs.**	**Gemba Learning**
While this author sees the value of preparation through coursework, the most specific learning regarding process occurs at the place of work.		Treat each day as a learning experience and then apply what was learned through continuous improvement.
Staffs Improve Process	**vs.**	**Line Managers and Teams Improve Process**
Delegating and outsourcing issues.		Manager directly involved in understanding and improving the processes over which they preside.
Decisions Made Remotely With Data	**vs.**	**Decisions made on the Gemba with Facts**
Rather than solving problems via spreadsheet.		Go to where the processes occur to identify problems and make decisions.
Standardization by Senior Staff	**vs.**	**Standardization by Line Managers/Teams**
Creating processes and procedures without involvement from process owners.		Standardization of process influenced by the people touching the process to avoid unintended consequences and difficulties.
Go Fast to Go Slow	**vs.**	**Go Slow to Go Fast**
Pressing staff and employees to move ahead quickly without full understanding of all issue and input from all process owners from concept to steady rate production.		Take time at the beginning to thoroughly evaluate alternatives, hidden issues, and unforeseen synergies and benefits.
Vertical Focus	**vs.**	**Horizontal Focus**
Focus is primarily on the internal vertical customer (CEO or next manager).		Focus on final customer and across the organization to recognize true value stream and *muda* that hinders the flow of value to the customer.

2.7.1.3 ***Vision – Aligning Everyone's Motives***

Mission and vision statements are constructed by the President and senior staff at the highest levels in a company and appear on the wall behind the receptionist, on annual statements, and possibly as an integral part of an email signature block. As an employee of several large companies, and interacting with other businesses and suppliers, my experience has been that these statements have little direct application to most of the employees on a daily basis. What differentiates the Lean enterprise is a passionate, hands-on approach to communicating the company's ideals, goals, and future states by the leadership themselves (Fine, Hansen, Roggenhofer, 2008).

2.7.1.4 ***Change Agent***

More than just a passionate leader, a *change agent* is also deeply knowledgeable of Lean thinking and tools required. This individual may be a member of senior management or even CEO, but may also be a consultant or internal expert empowered by leadership. This individual or small team is instrumental in pushing out old processes and instilling new processes. This action by the change agent must be undergirded by an effective change agent team that facilitates the adoption of Lean Thinking (Philippe Arrata, 2007).

Bringing people through a Lean transformation can be very confusing and disconcerting. In fact, no one more than Taiichi Ohno, who developed and nearly single-handedly implemented the Toyota Production System (TPS), knew that often it is only the Lean leader that is the driving force for adoption of the principles (Ohno, 1988).

2.7.1.5 ***Tenacity through the Conversion***

Tenacity is required through the process of adopting and integrating Lean philosophy. In my research there were many examples of success or failure hinging on the dedication of a few individuals at critical times. Jose Zabaneh, a production line manager at a company called Lantech, was such an individual. The company president,

Pat Lancaster, had committed to fully adopting Lean philosophies in order to turn his shrink-wrap machine company around from possible financial ruin. After many failures and false starts, the team was tempted to give up. Jose was quoted as saying:

> *I was so fed up with our failures and so taken with the logic of the new system that I threw my heart into it* (Womack J. P., 1996).

Lantech went on to extraordinary success and is still operating with Lean philosophies today as the world's largest packaging device company (Lantech, A lean way of life, 2010). Tenacity is required because the process often includes a number of stumbles as it moves ahead. Like golf, many of the concepts do not seem natural at first and must be learned over time. Inevitably leadership will see push back. A strong leader and senior staff must be stalwart through this time with training, demonstration and more training. According to Jim Womack in Lean Thinking*:*

> *Three years is about the minimum time required to put the rudiments of a Lean system fully in place and two more years may be required to teach enough employees to see so that the system becomes self sustaining.*

2.7.1.6 ***Focus on the Value Stream***

Departmental barriers create handoffs that can hide issues in the process. If an engineer is unaware of exactly how the selection of a part or component affects the downstream process, he or she will likely select a part strictly for its function and not the one best suited for the particular manufacturing facility or part of the supply chain. In fact, the selection of a unique part can inadvertently create an entirely new supply chain path with all of the overhead and expense that follows. The remedy is to have each contributor see the whole process and understand where both value and waste are created (Womack, 2011). This can be done through significant restructuring of the organization or improving continually the horizontal communications and handoffs between divisions as discussed in section 2.7.1.1.

2.7.1.7 *Sustainment*

Sustainment refers to the relentless and unending pursuit of value for the customer and destruction of waste over time. My experience has shown that sustainment is a fragile thing where efforts and initiatives lose momentum repeatedly despite great initial enthusiasm. This is, in fact, what spurred the question and provided impetus for this report.

So how can Lean activity be sustained? The proper foundation must be laid and built upon continuously. Pratt & Whitney is a very good example of this and is included in the case study below. But even Lean companies can cease to be Lean. Wiremold, another case below, sustained successful Lean operation for years only to be acquired by a company that does not espouse Lean thinking. All the positive changes that were made have been all but dismantled (Emiliani, 2003 and 2007).

2.7.2 THE TECHNICAL FACTORS

2.7.2.1 *Core Technical Knowledge*

A company wishing to create value must examine its own capabilities in light of a given customer's needs. If a company is trying to compete in a market in which it lacks the basic technical prowess no amount of efficiency will help it succeed against superior competition. This situation may arise through poorly advised acquisition strategy or overly optimistic market expansion plans. This must be fixed before Lean will really help either by divestiture, hiring the right expertise, or, if possible, ramping up in technical acumen with the current staff (Womack, 2011).

Having technical acumen, but lacking understanding of customer value is also waste. Providing more features than the customer wants or needs is a waste of development time, material costs, manufacturing costs, and possibly marketing efforts. The goal is to balance customer needs with company skills (Dolan, 1997).

2.7.2.2 ***Deep Understanding of Lean***

From examples in the case studies below, a fundamental part of true Lean application is having a stop-at-nothing attitude towards meeting customer expectations through eliminating waste, improving quality, and reducing costs through an engaged workforce. Fundamental to execution of Lean is a focus on five steps as delineated in Gemba Walks: Value, Value Stream, Flow, Pull, and Perfection (Womack, 2011).

Value: Value is what the customer actually wants and needs. The term 'Voice of the Customer' (VOC) is often used in Lean circles and means understand what your customer's true needs are and where your company can provide for those needs. Anything beyond meeting the need or desire of the customer is waste. You may have an extraordinarily elegant design and build it perfectly, but if there is no market for it, it is worthless. It creates no value for the customer.

Value Stream: Map of the resources and activities used to create value for the customer. Value-Stream-Mapping helps visualize the process and makes waste more visible in the process by showing every step required for the end product to come together. Figure 4 below shows a simplified example of a value stream map that might be generated. Helpful details include lead times and shipping costs. A full review of value stream mapping can be found in Learning to See (Rother, Shook, 2003).

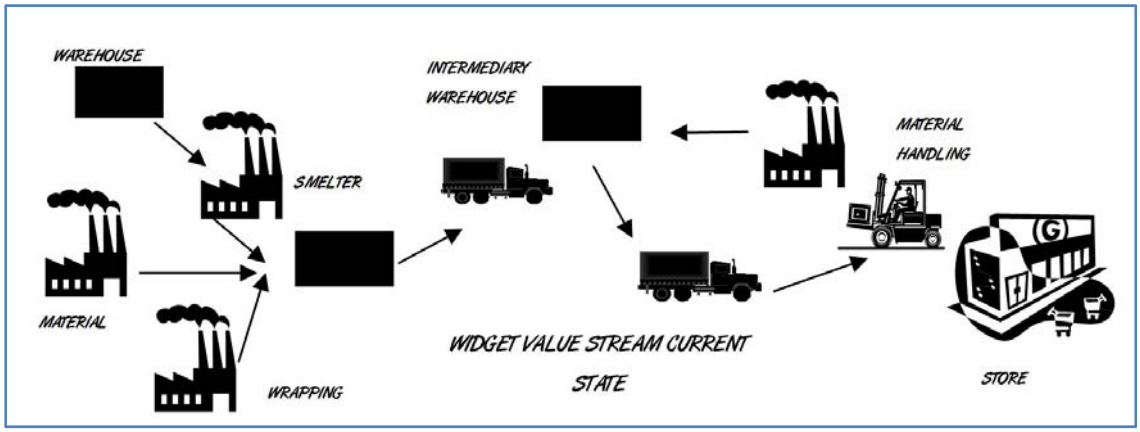

Figure 4: Value Stream Map, Current State

Flow: Every part and subassembly on a line move forward at the same rate. Leveling out the workload, or *heijunka,* is applied by allowing employees to flex to different functions when work varies. In Japan at the time of Deming's visit, the factories were small and were required to build a variety of products. Rather than limit the variations in product, Toyota learned to change over to different products in the same line quickly. This became a key component in supporting flow.

Pull (from the Customer): Is your process efficient enough to respond to the customer on demand? If not, what can be done to achieve this without adding inventory? This essentially refers to the concept of *Just in Time* (JIT)[ii] manufacturing where inventory is reduced and product is not let into the system until demand exists. This reduced inventory frees up capital and allows the process to change quickly due to changes in the market or customer demand.

Perfection: The job is never done. Once inefficiencies are effectively eliminated from the process, the next set of challenges is made visible.

2.7.2.3 ***Lean Tools***

Below is an important but by no means exhaustive list of tools and brief explanations that can be very helpful for a company wishing to operate within the philosophies of Lean.

5S Foundations: 5S is a workplace organization methodology that uses a list of five Japanese words: *seiri, seiton, seiso, seiketsu and shitsuke* that equate to sorting, straightening, sweeping (systematic cleaning), standardizing, and sustaining the discipline. To support an environment of efficiency and to enable visibility of the value stream, the workplace must be clean and orderly. It is also important to have continuous education about maintaining standards (Hirano, 1990 and 1995).

A3 Communication: The A3 is a communications tool that has only the critical information necessary to capture and convey what needs to be communicated on one sheet of paper (which happens to be the paper size designation and source of the

name). The A3 consists of Background, Current Conditions, Goals, Analysis, Proposal, Plan, and Follow-up. A helpful component of the A3 is the standard list of categories and questions including a section for the *5 whys*[i] that promotes discovery of root cause by repeatedly asking why each time an answer is found. This in turn promotes thought and encourages problem solving. The A3 is a clear, methodical, practical, and consistent method for capturing and relaying critical information and can cut through unnecessary bulletized fluff in so many PowerPoint presentations (Rother, 2003).

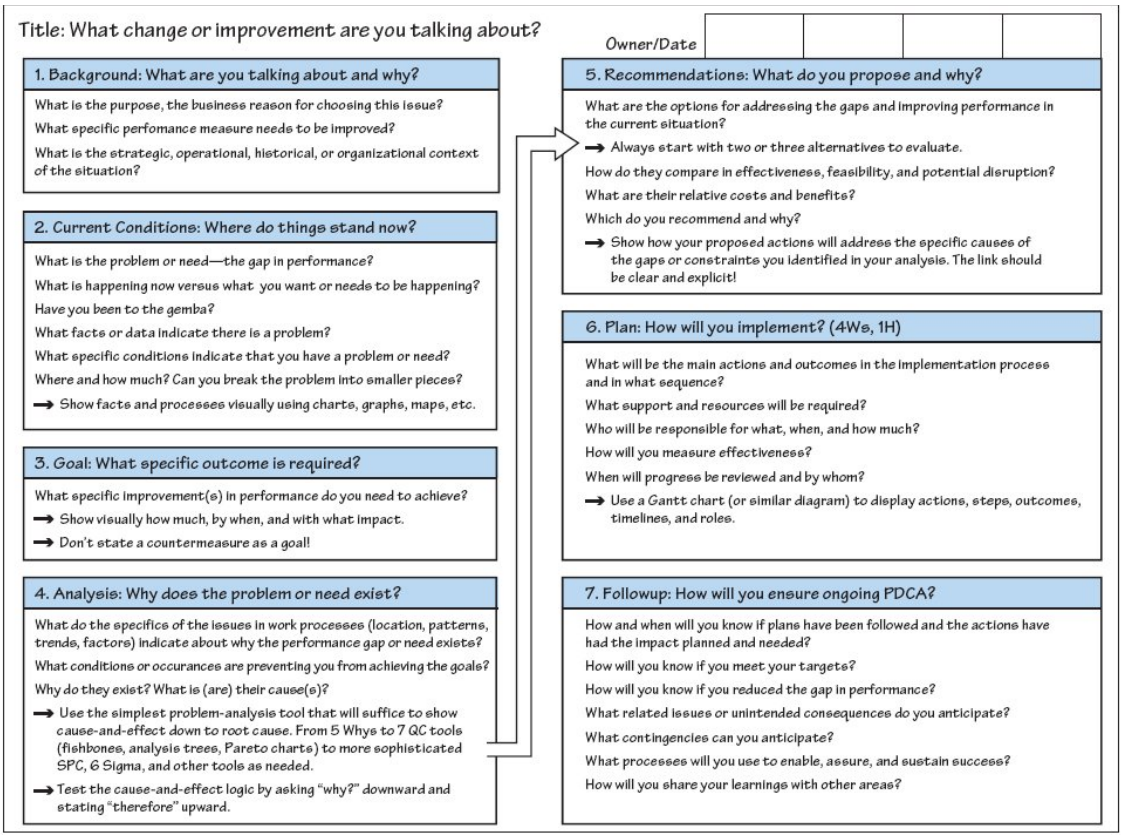

Figure 5: A3 Layout (Shook, 2008)

Heijunka: Refers to leveling out the production line to limit surges and even out the flow. In a flexible line where multiple orders for varying goods are taken, both the number of orders in any hour/shift and the specific type of order will vary. It is necessary to level out these fluctuations with small buffers along the process. This

would seem to go against the concepts of Lean where inventory is removed. The point here is that the inventory buffers along the line cause much less waste than the effect of fluctuating orders (Liker p. 12).

Kaizen: Simply means improving what you do every day. The thought is not to wait for a problem and then implement *Kaizen* to solve it, but to head off and root out issues in the mindset of continuous improvement (Deming, 1982). *Kaizen*s are based on the Plan-Do-Check-Act cycle promoted by Deming and provide a structured format for establishing the current state of a process, the desired future state, and the means and methods to get there. Equally as importantly, the *Check* and *Act* portions of the cycle indicate consistent monitoring of clear metrics required to know if you are achieving your goals and working towards or achieving the future state (Masaaki, 1986).

Kaikaku: In contrast to *kaizen*, which is used far more often, *kaikaku* means *radical improvement*. This is a disruptive tool that is used, for example, to completely deconstruct and rebuild production flow by moving heavy machines and work areas into new locations to promote an efficient value stream. It is also used in the razing and reconstructing of management hierarchy from a vertical to a horizontal organization, eliminating unnecessary layers of management and poor communications channels in the process. (Womack, 2011).

Jidoka: Means *Automation with a Human Touch*. Jidoka refers to the principle of fixing problems as far up stream as possible. In production, any rework required down-line is assessed and the fault source determined. Rather than continuously fixing an issue that occurs earlier in the process, the issue is taken to the source (Ohno, 1988). Applying this philosophy to the product development process is often referred to as *Front-Loading* (Anderson, 2008).

Set-Based Approach: A radical departure from the *normal* way of approaching product design, it is a subset of Front Loading. Set-Based approach is Toyota's approach to concept design. Point-Based design describes a process where two or

perhaps three concepts are evaluated and down selected at a very top level and a single concept is brought forward. While milestones are intended to be hard dates in both the Point-Based approach and Toyota's Set-Based approach, the Set-Based approach mitigates risk of schedule extension by having numerous concepts and approaches to solve a particular subsystem design. As the date approaches, these concepts are combined or culled. When the firm milestone date arrives, the least risk concept is put forward. By spending time, resources, and money at the front end fully examining every possibility and solution, the much more costly system level schedule slips, late verification testing failures, and pushed out product releases are eliminated. By examining the concept more thoroughly, a lower overall product cost can be achieved (Kennedy, 2003) .

Project to Project Knowledge Transfer: Project to project knowledge transfer leverages previous projects by transferring problem and solution-specific information to new projects through lessons learned, or other capture means. Companies often neglect systematically capturing knowledge of what works and does not work. This effort is often not budgeted and seen as a luxury the program cannot afford. This causes rediscovery of old problems in new projects (Anderson, 2008). My personal experience correlates with this. In contrast, Toyota carefully controls checklists and uses them as a means to capture and convey lessons learned. This knowledge capture is important to shortening the design cycle by capturing not only what works, but what does not work (Sobek II, 1998).

Lean tools, like the ones listed above, by themselves neither represent Lean thinking nor ensure success to the organization. Lean tools exist rather because they were needed to facilitate the basic philosophies of Lean thinking. Without the right leadership mindset lean tools will not be as beneficial. They are useful for creating a learning organization, and help the company to see the processes involved in creating value for the customer as well as to see where *muda* exists to eliminate it (Marchwinski, 2011).

2.7.3 The Human Factor

Tools and technical prowess will not ensure strong and lasting Lean transformation without an engaged, motivated and knowledgeable workforce. Key to the success of any endeavor to improve a business is an understanding of the motivation of the employee (Liker, 2004).

2.7.3.1 ***Respect for Employees***

Respect for the employee is an attitude that is promoted highly at Toyota. If there is a problem on the factory floor, for instance, the supervisor or manager will first only collect information with no presupposition as to cause (*5 whys*[i]). Then, with the stance that there is a fault in the process or product, not the individual, an attempt is made to change or improve the process. If all other avenues are exhausted and it is determined that the employee was at fault, specific training is provided. Only as a very last resort is the employee removed from that function. If that occurs, the attitude is that the leadership was in error to assign that employee to that job. Realignment of function is next and only very rarely would an employee be terminated (Liker, 2004).

When a company is faced with hardship how it treats the employees truly speaks to how it thinks of its employees. The correct course of cost cutting is to first cut corporate dividends, then salaries and bonuses of the top management, then salaries of the top half of the management structure, and only if these efforts are not fully successful are the employees asked to reduce their salaries or accept voluntary discharge (Deming, 1982). It seems the Golden Rule is not lost on Deming. What is most unnerving is that Deming wrote this sentiment in 1982, and within just the past year, twenty-eight years later, we as a nation were appalled at the huge bonuses accepted at many large companies who received billions in aid from the government. We are still not listening to Deming.

2.7.3.2 ***Workforce Engagement***

To function in a front loaded, Set-Based type of environment, where responsibility is pushed down to the lowest level possible competent employees must fully understand the systems, processes, and technologies, with which they work. Each supervisor or manager over a technical group must himself/herself be an expert at the things done within that group. An environment of careful supervision where many more questions are asked than orders given creates a teaching environment that not only provides better products more quickly, but provides the employees themselves with better sense of accomplishment when success is achieved. This environment changes employees from merely following orders in machine like fashion, to solving their own problems and asking the right questions, participating more fully in the solution (Sobek II, 1998).

Morale and the use of Award and Suggestion Programs

Award and recognition programs should be utilized as a matter of course for any successful Lean enterprise. Toyota uses many awards and recognition incentives to keep their employees motivated. One program is the perfect attendance award. All employees with perfect attendance get to go to a very nice banquet annually. At the ceremony, a lottery is drawn and several employees drive home with free Toyotas, taxes paid.

Toyota has utilized a suggestion program from the beginning. Not only does it provide an avenue for engagement of the employee, but consider the accumulation of many ideas over the years providing for tiny (or large) improvements that can shave seconds off of operations, eliminate processes, or other means of lowering costs or improving quality. Over time these small ideas can add up to enormous improvements. Linking suggestion programs to awards can motivate continued participation and accelerate these gains.

2.7.3.3 ***Motivational Theories***

Toyota employs five motivational philosophies including characteristics of Maslow's hierarchy of needs, Herzberg's Job Enrichment theory, Taylor's Scientific Management approach, Behavior Modification, and Goal Setting (Liker, 2004). One of these theories is expanded below.

Goal setting theory[iii]**:** States that given a goal that is both specific and difficult, once that goal is achieved, that individual has greater confidence in his or her own ability to achieve additional, perhaps more challenging goals. (Locke, Latham, 1990). This is part and parcel to creating an engaged workforce. Lean transition is a stressful time and some employees will likely make mistakes initially (Fiume, 2004). Understanding of goal theory will help guide how to handle this situation. For instance, ensuring employees know that mistakes do not equate failure and avoiding punishment for mistakes, contrary to the theory, will help maintain enthusiasm and forward momentum where employees remain in the goal-self efficacy loop.

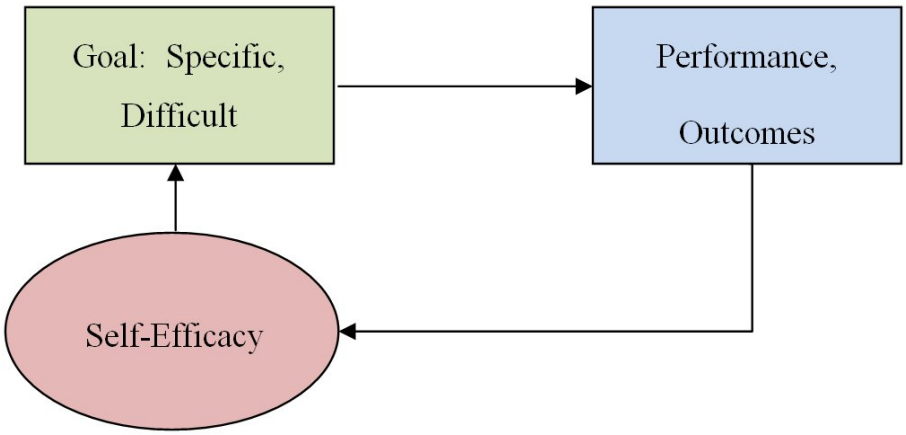

Figure 6: Goal Theory

A glaring issue with the implementation of Lean is that fewer employees are needed to do the same job. As a manager tries to involve his or her employees in Lean activities, how can motivation and performance be sustained? A motivational theory that frames this situation is the Expectancy, or *VIE* theory.

Expectancy theory[ii]**:** Ties motivation to expected outcome and consists of three components: Valence, Instrumentality, and Expectancy. Each component must be high, or positive, to result in good effort by the employee.

$$\mathbf{EFFORT = (V * I * E)}$$

Valence (V) is the desirability of the expected outcome. Instrumentality (I) is a belief that a specific level of performance will lead to a particular outcome. Expectancy (E), finally, is the perception that a particular level of effort will lead to a specific level of performance. Each of these components must be favorable for effort to follow.

If the employee does not expect good performance to result in a good outcome, meaning he or she expects the elimination of their job or their neighbor's job if their performance is good, instrumentality will be low. If this is the case, all motivation ceases and level of effort will fall off precipitously.

The application is that after any necessary reductions in force are completed in order to preserve a high level of effort the leadership must preserve instrumentality by absolutely ensuring that no further reduction in force will occur due directly to efforts towards Lean. Theoretically, if Lean is fully implemented demand will increase resulting in growing, not diminishing, headcount. A short term method to deal with excess labor is to promote the best and brightest to *kaizen* teams to find additional ways to reduce waste or increase value (Womack J. P., 1996).

2.7.3.4 ***Hiring and Firing to Preserve Lean Initiative***

Fair methods to assess performance do not negate the need to fire or reposition employees. During the transition process there are some who are enthusiastic about the change and the majority is generally tentative with a wait and see attitude. There is often a small percentage that militates against it at every opportunity. A few of these individuals within a company can be a poison to the whole group. It is better for the organization to remove that employee from the ranks (Fiume, 2004).

Hiring is the front line defense against such issues. Ensuring that the applicant is compatible with the company culture is critical. This is known as *Fit* and should be addressed during the interview process[ii].

2.7.1 The Crisis Factor

Finally, each company included in the case study below that successfully adopted Lean principles has faced a crisis that if left uncheck could have spelled the demise of the company. Toyota experienced the post WWII economic collapse and run-away inflation. Wiremold, P&W, and IEC all experienced financial crisis at significant levels. This is not a direct factor or one that should necessarily occur before a Lean transformation can be implemented, but merely an observation. Perhaps it is simply a matter of human nature that greatness comes out of adversity and less often in comfort.

2.7.1 Summary of Lean Factors

It is not enough to implement lean tools piecemeal where deep understanding of Lean principles does not exist. The underlying philosophies must be applied across an organization with particular methodologies by management, high levels of technical proficiency in the application of the appropriate lean tools, and a realization that the human element, that includes respect, engagement, and motivation, are synergistically related and key to successful inculcation of Lean into the company culture. It also appears that success is most often achieved when there is no other recourse and crisis looms. This assertion will be addressed further in the case studies below.

3 Study Methodology

I began researching the case studies with the foundation of secondary research of various concepts, tools, methods and philosophies as summarized above. Then, through both primary and secondary sources I compared attributes of four companies that desired to improve quality and reduce costs to see what similarities and differences existed. I then correlated key elements of the successful companies and contrasted against the unsuccessful company.

I examined and analyzed four cases where the company had a desire to implement Lean principles to positively affect their business through lowered cost of operation, better quality, and better customer value. The first two companies, Wiremold and Pratt & Whitney, are examples of success stories. This established a baseline for success. I then followed the same process with the next two companies using primary research and investigation to discover whether these companies exhibited the same characteristics and whether or not they would be considered successful based on the criteria established with the first two companies. The results of this study are found in following sections.

3.1 Wiremold[iv]

Wiremold is a manufacturer of extruded plastic electrical raceways. In 1988 Wiremold procured Brooks Electronics of North Philadelphia, PA, to branch into the surge protector power strip business. Brooks offered not only a new business line, but a close relationship with W. E. Deming. Company head Gary Brooks had incorporated Total Quality Management into his business and had taken half of his total workforce to Deming's week long seminars before the purchase. Wiremold saw the value in Deming's methods and attempted to incorporate TQM and the philosophy of JIT to the rest of Wiremold.

3.1.1 The Crisis Factor

With limited knowledge of Lean, more harm than good was done to the company. Though sales only suffered a few percent due to late deliveries, costs ate into nearly all profit due to expedite charges on freight and additional service staff to handle souring customer relations. To add insult to injury, the implementation of TQM had uncovered manufacturing equipment sorely in need of repair and updating. These costs burned up almost all of the remaining profits. Their company was in crisis.

3.1.2 The Management Factor

Modern vs. Lean Leadership

When Art Byrne was hired President and CEO of Wiremold in 1991 he already had a deep understanding of Lean principles. Art had been the overseer of successful Lean transformation of not one but eight separate businesses in the Danaher group before coming to Wiremold.

The Lean Conversion- Radical Change then Incremental Change

Based on his experience and understanding of Lean, Byrne knew that if Wiremold was going to avert catastrophe and begin to fully implement Lean methodology *kaikaku*, or radical change, was required. Byrne began upending the business with numerous significant changes that ranged from removing a substantial number of senior managers that could not or would not accept the new methodologies to significantly restructuring production lines to improve flow. He recreated the Wiremold organization into a horizontal organization aligned with the value stream of the product. Further, Byrne was the only employee who understood the complete philosophy of Lean at Wiremold and therefore vigorously trained every individual personally.

Vision – Aligning Everyone's Motives

Byrne‘s vision was to maintain sales volume with half the people and half the floor space through application of Lean principles. His vision included remaking each

production line to enable Lean flow, restructuring and flattening the organizational structure, reducing inventories, and implementing substantial training. He also made it clear that Lean was not a passing initiative to try and then move on. Byrne made clear that everyone was to support the initiative, enumerated the benefits concisely, and informed everyone that if they did not coalesce they would receive help in finding new employment. This left no room for going back. The vision was clear (Fiume, 2004).

Change Agent

Byrne, as described above, was his own change agent. He lead with passion and was not afraid to make sweeping changes, but took care to provide substantial severance packages for those who were laid off. He also made it very clear to the remaining employees that there would be no further layoffs and took time to connect with the employees.

According to Byrne, the single most effective action in converting an organization to Lean practices is for the CEO to lead the initial improvement activities himself (*genchi genbutsu)*. Byrne's observation was that most American companies fail right at the outset because of a lack of *genchi genbutsu* and are too timid and take measures that are far less than what is required.

Tenacity through the Conversion

Byrne had to make difficult and sweeping changes within the company but stayed the course until results were achieved. Table 3 provides empirical evidence of his tenacity through the difficult changes.

Focus on the Value Stream

Byrne was successful in restructuring the management hierarchy to create a horizontal structure and in doing so provided visibility to the value stream. For instance, he assigned Joe Condeco as the Value Stream Manager of a TelePower™ product. This meant giving him complete responsibility including profit and loss accountability. His whole team, including planners, manufacturing engineers, production supervisors, and

operators, was co-located on the factory floor adjacent to the production cell that produced the product. By doing this the whole team could see the value stream.

Sustainment

Byrne continued his vigorous pursuit of value and elimination of waste throughout the 1990's and into the early 2000's until his retirement in 2002. Over an eleven year period using Lean philosophy he grew Wiremold in size 400%, increasing earnings by 1300%, and increased the net worth over 2500% (Bio, 2010).

In July 2000, French electrical manufacturer Legrand SA acquired the Wiremold Company for $770 million. Unfortunately, Legrand, a batch-and-queue mass production manufacturer, systematically dismantled all of the lean processes and methodologies created and sustained by Byrne and his staff.

This is a stark example of the fragility of Lean and dependence on strong leadership that understands Lean principles. Without strong leadership, entropy takes over quickly (Emiliani, 2003 and 2007). This is a great disappointment for Lean proponents; however, a review of Legrand's 2010 annual report shows consistent profits. Could profits have been higher if Legrand came to understand and implement Lean across its global business? Further study is required here to determine the full impact to Wiremold.

3.1.2.1 ***The Technical Factors***

Core Technical Knowledge

Byrne strengthened the focus on the core business and primary value to the customer. The product development department paired thirty separate projects that were active in the queue down a few targeted high value projects. By doing this the time to complete a project, previously three years or more, was reduced to six months and tooling costs were reduced an average of 40%.

Understanding and Use of Lean Tools

Art Byrne single handedly brought Lean understanding to the company and quickly inculcated disciples to keep the momentum moving. Wiremold's companywide grasp of Lean grew through rich use of *kaizen*, value stream focus and many other Lean tools. Hundreds of weeklong *kaizen* activities were initiated and involved nearly every employee. For example, a special team was set up to focus on the supply chain and worked with vendors to apply Lean to their processes as well. This helped to ensure smooth flow of material from the suppliers, through the continuous flow lines within Wiremold and to the customer. Further, product line personnel including engineering, production supervisors, and manufacturing were collocated on the shop floor to expedite response to any issues.

3.1.3 The Human Factor

Respect for Employees

Wiremold practiced the foundational principle of *respect for people*. Profit sharing was increased from 1.2% of profit sharing to a generous 7.8% based directly on profits. This connection was communicated clearly and often in simple terms so that everyone could understand it. This tied the company's performance goals tightly to the employee's own efforts in a tangible way. On-line blog references are replete with glowing anecdotes of the wonderful work environment created by Art and the Lean philosophies (Meyer, 2009).

Workforce Engagement

Individuals were included as part of the solution and were invigorated by the challenge to continuously look for ways to improve. Moving to the horizontal structure also helped provide strong workforce engagement (Meyer, 2009).

Hiring and Firing to Preserve Lean Initiative

After the initial *right sizing* there were no layoffs under Art Byrne. Art tried to be as fair as possible with those he did have to let go with generous severance packages. Since Legrand SA took over and dismantled the Lean activity, numerous layoffs have occurred (Meyer, 2009).

3.2 Wiremold Results

To summarize, the changes in metrics attributed to the Lean transformation are summarized in Table 3. Beyond 1995, revenue at the company grew by an average of 19% a year to a mark of $770 million in 2002 (Bio, 2010).

Table 3: Wiremold Reported Lean Efficiency and Cost Improvements

	Batch-and-queue 1990	Flow 1995
Sales per employee	$90,000	$190,000
Throughput time to produce average product	4 to 6 weeks	1 to 2 days
Product Development Time	3 years	3 to 6 months
Number of Suppliers	320	73
Inventory turns	3.4	15
Space Required (indexed to 1990)	100%	50%
Sales (indexed to 1990)	100%	250%
Operating Profit	100%	600%
Profit Sharing (% of Straight Wage)	1.2%	7.8%

3.3 Pratt & Whitney[v]

Pratt &Whitney (P&W) is most like the two defense contract companies with whom I have firsthand experience. The original P&W Company was created by Francis Pratt and Amos Whitney in 1860, both of whom were originally employed by Colt to manufacture of components for the Colt pistols and rifles. P&W grew from a small workshop to a massive and very successful manufacturer of aircraft engines.

Through a series of ups and downs, by the late 1980s P&W were experiencing chronic reliability issues, increased competition, and missed direction on the size and

specification of aircraft engine being demanded by customers. With a design cycle of 4 years, rapid response was out of the question.

Several initiatives were tried including rearrangement of various factories into streamlined *focus factories* implementation of the Integrated Product Development (IPD) system and use of Total Quality Management principles. These improvements were moving in the right direction but not rapidly enough. Savings on cycle time and cost was about 20% over earlier methods.

3.3.1 The Crisis Factor

In June of 1991 business began dropping off precipitously as the world recession set in. 1662 engines were ordered in 1989. That number was down to 364 in 1993. In 1992 a $283 million dollar loss was put on the books. Mark Coran of parent company United Technologies Corporation (UTC) was sent to P&W for what was thought to be minor course corrections. What he found was a genuine crisis.

3.3.2 The Management Factor

Modern vs. Lean Leadership

Coran was enthusiastic about implementing Lean but needed additional help in Leadership. The president of P&W at that time had been a lifetime employee there and did not have the mindset needed to lead a Lean enterprise. Coran tapped the president of UTC, George David, for help. Karl Krapek had studied Lean principles for years while working at GM but was not in a position to fully utilize his knowledge. He became president over the Carrier division of United Technologies two years prior and was well into a Lean conversion there when George David called him and requested he move over to P&W. David also suggested bringing in a Japanese Lean consulting company who had helped Art Byrne in the past to help with the conversion.

The Lean Conversion- Radical Change then Incremental Change

Early in the process the team was met with immediate resistance to the vision and plans. As a result senior staff was reduced 50%, from 72 to 36, and the president was replaced with a Lean thinker. Additionally, 2.8 million of Pratt's 11 million ft^2 of manufacturing floor space were closed. All production lines were targeted for conversion to continuous flow from the batch-and-queue system using Lean tools and techniques. Changes of this scale occurred only initially.

Vision – Aligning Everyone's Motives

Chihiro Nakao, a Lean consultant, set the vision by laying out the following goals:

- Reduce engine assembly time from thirty days to three
- Cut factory floor space by 50%
- Reduce headcount by 66%
- Reduce inventories of parts and finished goods by 90%

The vision also included cost savings target of 35% over 4 years and drastic reduction in supplier base. Coran and others vigorously communicated the goals through Lean thinkers within the organization and also through the consultants.

Change Agent

Coran realized that he needed help in creating a change agent. As mentioned above, help came from the Japanese consultants, Yoshiki Iwata and Chihiro Nakao. Coran also brought in Bob D'Amore from UTC who had learned Lean thinking through his time at Harley Davidson in the 1980s. D'Amore was tasked with converting P&W batch and queue process to continuous flow. UTC's president, George David, provided the appointment of a strong Lean thinking president, Karl Krapek. This team embodied the no-holds barred approach to radical change with respect. This characteristic was important because of the daunting requirements and extraordinary measures required for Lean transformation.

Tenacity through the Conversion

Firmly dealing with a strong mass production mindset within the management and an entrenched union was a high hurdle that the team addressed through strength and resolve.

Over the course of three years, with all of the extraordinary changes, the balance sheet had yet to improve. Coran stated that he would have been fired except for the fact that George David, and Karl Krapek understood that implementing Lean was a long process and metrics often look worse before they get better. According to Coran the key was to continue forward with an, "absolutely steady course."

Focus on the Value Stream

A production site that was responsible for the majority of P&Ws revenue was having trouble even turning profit. Large processing machines used to help form turbine blades were poorly positioned. First time through quality was 10% meaning that 90% of the product manufactured at the facility was reworked. The team went to work. First, a study of the value stream was conducted and an optimized future state arrangement was generated. Then, the line was reconfigured according to the plan. This included moving the giant monolithic machines into production cells which would reduce the distance traveled for both operators and material. Once the changes were completed, the following results were achieved:

- Overdue parts costs fell from 80% to 0%
- Inventory reduced 50%
- Manufacturing costs for many parts was reduced by 50%
- Productivity increased by 2X

Sustainment

All indications point to a successful sustainment of Lean Thinking up to the date this paper was published. When Karl was promoted to president of UTC, he placed Louis Chênevert in the office of President of P&W. Louis was a 20 year staff member and

Executive Vice President over P&W. And unlike Wiremold's new parent company, United Technologies Corporation leadership understands and continues to foster Lean Thinking. With leadership lineage still in place by Karl Krapek, Mark Coran, and Louis Chênevert, continual learning and growth are assured. Further evidence of P&Ws success in sustainment is found in a press release dated May 6, 2011. The release described the opening of the P&W Canada Mirabel Aerospace Centre (emphasis added):

> *The P&W Canada Mirabel Aerospace Centre was designed and built to achieve the highest standards of operations excellence and sustainability. Engines will be assembled according to the* ***latest Lean principles*** *to ensure efficiency and flawless quality.*
>
> *The centre incorporates an overhead and automated indexing flow assembly line allowing engines to be assembled horizontally and ergonomically – a first for aerospace engine manufacturers.* ***The engines will be assembled in an optimized and Lean process*** *starting from the front and progressing towards the back with a specialized workforce trained to perform multiple tasks for maximum flexibility based on production needs. The manufacturing processes have been designed to maintain the highest standards of safety and ergonomics.*

3.3.3 The Technical Factors

Core Technical Knowledge

P&W is the world leader in aircraft engine technology. GE and Rolls Royce offer competition, and sometimes partnerships in this field as well. There is no doubt that the technology is understood and executed well. What sets P&W apart is their agility provided by Lean. Before the conversion, under the confines of a four year development cycle, a wrong assumption about what motors would be in demand four years later nearly ended the P&W business. Now, with the foundation of Lean, P&W not only has a better focus on the value to the customer, but can react much more quickly to changing demand because of the shortened development and build times.

Understanding and Use of Lean Tools

The right individuals were brought in the early 1990s to promote and instill the use and of Lean tools. These tools were executed from a foundation of a deep understanding of Lean and enabled the restructuring of production to allow visibility of the value stream. Rework was virtually eliminated through the new QA system that utilized the perfection of *flow* to discover root causes by investigating the number of times mistakes would interrupt the flow. The phenomenon at work here is that continuous flow and perfect quality were always achieved together with the use of *jidoka* that employs stringent root-cause analysis through methods like the *5 whys*, and follows with specific corrective action in the PDCA or Plan, Do, Check, Act cycle (Masaaki, 1986).

Factory floors were aligned for optimal flow and the whole value stream from vendor to customer was rethought where built up subassemblies came in ready to snap together, allowing for substantially shorter process times. The development centers were reorganized into Module Centers that aligned on products rather than functions, streamlining product development. Many other tools and techniques were utilized and continuous improvement continues today from the engaged workforce.

3.3.4 The Human Factor

Respect for Employees

One significant step P&W took to promote respect for the employee was to dismantle the old Quality Assurance process. The process not only created 60,000 Material Review Board[vi] reports annually, it also created animosity because QA staffs were continually checking up on production employees to make sure employees hadn't taken shortcuts on quality to meet targets making them, according to Coran, *the corporate superego or nagging nanny*. This system, while creating animosity, did very little to help P&W achieve quality goals. By utilizing the concept of flow with heijunka, defects are found and an immediate root cause is initiated, rather than simply fixing the error and deciding if it is okay to ship.

P&W has created a highly stylized graphic vision statement, shown in Figure 7, which embodies ethics and respect, a hallmark sign of Lean values.

Workforce Engagement

P&W had a deeply imbedded long history with the International Association of Machinists. Engaging the workforce and training them to become multi-skilled problem solvers was an incredible feat considering the decades of unionized mass production history. Suggesting a complete change in how union employees approached their job was an audacious but necessary goal. Specific changes included changing from a single skill, one machine operator arrangement, as defined by union established rules, to a multi-machine, multi-skilled operator to accommodate the Lean production cell and flex concepts. Coran and Krapek met with the union leaders and final agreements were reached. The union was persuaded to adapt the new rules or face additional outsourcing and layoffs. At that point, the modified union mandates were functional in garnering participation from the employees. With proper use of tools, the right leadership, and the instilling of Lean thinking in the work force, engagement followed naturally.

Hiring and Firing

Initially P&W had 72 senior managers, most of who were fully engrained in the mass production batch-and-queue way of thinking. An enormous effort was made by Mark Coran, George David, and Karl Krapek, to deal with those who would not or could not adjust to the Lean philosophy. Total number of senior managers was reduced from 72 to 36. Only 17 of the 36 were original managers. Some managers genuinely tried to work with the new systems but did not have the ability. These managers were moved rather than fired to respect their efforts. Headcount for the remaining levels of employment including manufacturing had to be reduced from 51,000 to 29,000. Negotiations with the International Association of Machinists yielded agreement after a promise that, as long as the new production targets were met, no work would be outsourced.

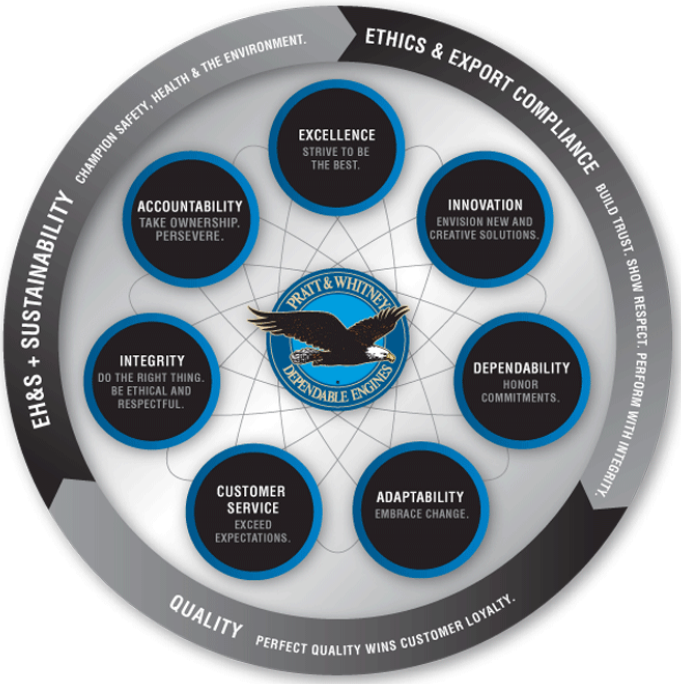

Figure 7: Pratt & Whitney Graphic Corporate Vision Statement[vii]

3.4 Pratt &Whitney Results

Table 4: Reported P&W Lean Conversion Statistics

	Batch-and-queue 1992	Flow 1995
Number of employees	51000	29000
Throughput time to produce average product	18 months	6 months
Product Development Time	4 years	Not avail
Number of Suppliers	320	73
Space Required (indexed to 1992)	100%	75%
Sales	100%	250%
Operating Profit	($283 mil)	($530 mil)*
Finished Goods Inventory (indexed 1992)	100%	30%
MRBs (indexed 1992)	100%	50%

*More significant in light of the 50% reduction in orders

3.5 Company A[viii]

A division within Company A was in the process of working towards adoption of Lean Product Development processes in 2008. I was able to research the progress and steps used directly and have included the results in this report.

This defense contract company is similar in size and complexity to the parent company of Pratt & Whitney, UTC. This company has gone through many changes including a steady process of conglomeration over time from numerous companies into a large, worldwide company. Key markets for this company include military avionics and equipment for land, sea, and air. In the mid 2000s a process of alignment was initiated and executed to make the new larger company more unified with common processes including Hardware Development, Procurement, and a number of other administrative levels. Overall, this process yielded benefits such as improving the ability for various sites to work together in *borderless* fashion.

Within the division involved in the Lean initiative there had been small pockets of interest in Lean principles and related areas such as Six-Sigma and Design for Manufacturability existed across the company. Teams were sometimes assembled to target cost savings or quality improvements. There had been no comprehensive Lean initiatives until a mid-level manager who had interest in Lean coordinated a *Lean Summit* in 2008 where significant senior staff members were gathered to look at the current state and suggest methods and direction for change. A wiki site was created and much excitement was initially generated; however, possibly due to lack of understanding of Lean principles within the larger management body, the success of this effort was not long lasting and little apparent change occurred at all.

3.5.1 The Crisis Factor

Several major factors including the economic collapse of 2008 and the inability for the U.S. Congress to create a budget, defense contract customers within the armed forces all but shut off funding for new development programs. Further, the core technology

for the largest production program within the division was not quite as advanced as the state of the art offerings from similar companies. A new technology was supposed to come on board but was delayed extensively which further impacted forecasts for the negative. These were certainly serious business issues and motivated the company to seek solutions. There was a round of layoffs and a consolidation of sites within the division. It was uncertain as to whether this was related to a Lean *right sizing* effort or a standard cost saving measure. The overall revenue numbers for this business unit were not made available to me.

3.5.2 The Management Factor

Modern vs. Lean Leadership

From observation, the paradigm for management style aligns best with the Modern Management category described in section 2.7.1.1 above. Management was looking to reduce costs and increase throughput in the design. The first action was to set aside a significant amount of capital to fund the cost reduction effort nationwide in the millions of dollars. The next action was to delegate the cost saving effort to teams within the division.

One team focused on the product development process with the intent to improve and implement Design for Manufacturability as there had been issues with product development handoff and lack of design for manufacturability that hampered improvements in manufacturing. Over the course, the team scope increased to Lean Product Development. Members of the team had experience with a number of Lean methodologies and other rapid design strategies like Rapid Prototyping and Concurrent Engineering. Based on my knowledge and observations, no one on the Lean Product Development Team reflected a deep understanding of Lean thinking as defined in this report.

The Lean Conversion - Radical Change then Incremental Change

By the end of the year 2010, the group had thoroughly reviewed the corporate design process and implemented *Lean hooks* within it, calling for Lean Design Reviews at critical junctions with the idea that there would be small teams cognizant of Lean principles that would review progress and suggest changes. The team rewrote the existing check processes and implemented line items in appropriate places to invoke, or at least promote, the use of Lean tools and methods. DFM reviews early on in the design process were required. Concepts such as front loading were defined in corporate SOPs.

This method seemed the best course of action based on the level of understanding and paradigms the group operated within. The Lean thinker, based on the research above, would be able to detect some issues hidden in the above paragraph. First the effort still operated with groups of knowledge holders rather than emphasizing broad direct involvement from every employee. Next, waiting on periodic design reviews before a Lean reviewer could come in and *inspect* the work was still an application of batch-and-queues of work. While making tools part of the existing corporate policy is a very good idea, the lack of a significant and disruptive *kaikaku* driven by top management leaves the probability of a true Lean conversion uncertain.

Vision – Aligning Everyone's Motives

With a lack of fundamental understanding of Lean, the vision for this team and the conversion was necessarily narrowed. There were targets for reduction of both time and cost of 20% reported on the intranet website, but the path was unclear. As mentioned, a push for total employee involvement was not performed. It was not entirely clear to me, an individual on a key performance team, what the overall objectives were beyond cost savings.

The Lean Conversion - Radical Change then Incremental Change

No *kaikaku* level changes were considered. This was not part of the thinking of the leadership.

In the spring of 2011 objectives were set to roll out with the new Lean check list. The manager who had organized the 2008 Lean Summit, and who in the interim was promoted to Director, was also brought on to replace the previous team leader.

Finding an existing program to initiate the new process proved difficult initially. While the process was backed by upper management, they cautioned that implementation of the process could not disrupt current programs. While many supported the ideals of Lean in production, there was unwillingness or lack of understanding within the engineering and product development groups as to how it related to design and development. This was likely exacerbated by the lack of Lean leadership like George David of UTC who would understand if a program performance dipped during Lean implementation with expectations of great improvement later. At length some courageous managers, who had in effect, been performing to Lean concepts already, were found to commit to the newly minted Lean processes formed nearly a year earlier.

In June of 2011 the company executed a layoff that affected half of the hardware design staff including some extraordinarily brilliant talent and an individual with substantial Lean experience from the Lean Product Development team. I do not have the information to say if it was part of a right sizing effort or simply cost cutting.

Change Agent

There were no change agents of the ilk of Art Byrnes or Karl Krapek. A strong leader with a mandate for moving forward, like those used by Byrne, would likely be necessary as many did not share enthusiasm of Lean methods. This lack of enthusiasm was likely primarily out of misunderstanding of Lean itself. For example, in a Lean presentation during a staff meeting an engineer spoke up and expressed that, in his opinion, consideration of producibility early in the design process was useless waste of

effort especially for one-off prototypes. The problem with this stance is if a prototype is shown to customers in the field and he or she suddenly wants tens or hundreds of them quickly it is almost impossible to react quickly enough in a cost effective manner with a product that is representative of a highly reliable production unit unless this forethought is put into the product and process up front.

The Lean Product Development Team leader was very motivated but, like the reticent program managers above, did not have senior management above him like David George who would promote disruptive *kaikaku* change. He would likely have needed some additional help if given the opportunity. A consultant was hired for a three day seminar on Design for Manufacturability and Concurrent Engineering as well. While his information was spot-on, it was only a part of the overall Lean philosophy. A three day seminar can be educational but does not qualify as a change agent.

Tenacity through the Conversion

Given the lack of strong mandates by senior management not only was the Lean initiative stymied, the team brought together to execute the transition lacked cohesiveness. Many of the team members who were active participants in the formulation of the processes in the fall could not or would not return in the spring. Immediate and pressing needs overcame the long term importance of this process. Eventually new team members were found and recruited, but this change over proved to steal a significant portion of the team's momentum. It was not until summer 2011 that they were ready to initiate a roll-out. The latest report as of the fall of 2011 was that no significant roll-out had been achieved and that *politics* had stymied the implementation. This could likely have been predicted based on the lack of key components of Lean and could have been predicted based on observations (Anonymous, 2011).

Focus on the Value Stream

The structure within Company A is organized as a matrix organization. Based on a comparison with Toyota's structure this should not severely limit Lean transformation

as long as proper training was performed to help employees see across their departmental boundaries at the value stream as Toyota demonstrates. Unfortunately, this training and direction was not being performed regularly and vigorously across all of the business areas. There was significant effort to include all of the right stakeholders early on in the product development process.

Sustainment

This Lean initiative is relatively new and has not had the benefit of time to see if sustainment of the efforts occurs. Unfortunately, sustainment, as we saw with Wiremold, is a very fragile thing. I do not believe it will occur unless the methods change and level of Lean application increases.

3.5.3 The Technical Factors

Core Technical Knowledge

This division had a successful business of legacy equipment refurbishment. The site had been involved with large highly technical, lengthy programs associated with technology demonstration and therefore did not have many large production programs. The latest product, fortunately, did have high volumes in the tens of thousands. The technology was reasonably competitive and the customer base was generally satisfied with the performance. The core intellectual property was inherited by another division and relatively new to this division. Turnovers and retirements broke some continuity in the knowledge base so a consistent and comprehensive knowledge sharing system was not in place leaving room for lack of full understanding of the key product technology and less than optimal utilization.

While these issues are not insurmountable, the technical factor having the most impact, as covered above, is a fundamental lack of Lean understanding. Technical design challenges can be overcome through superior process and an employee base engaged in problem solving. Without this, the cost per part, time to market, and quality issues can scuttle even the best design.

Understanding and Use of Lean Tools

As mentioned in length above, the Lean Product Development team did not understand the deeper concepts of Lean thinking. This necessarily impacted the implementation of tools. The Operations staff incorporated a morning walk around or *gemba* but probing questions were rarely asked. Training for Six Sigma and a new initiative to train and certify *Lean-Six Sigma* greenbelts was established in 2010. The training was excellent and very useful, but only a small number of employees participated in the class. The concept of total Lean enterprise conversion was not taught. Further, opportunities were not as available or as comprehensive as needed for a full Lean enterprise conversion.

There were bright spots regarding Lean application. Various training events had occurred over the course of several years in some areas of the company. *Kaizen* had recently been conducted with significant localized benefit on a program with a large amount of material flow. Where the company saw most success was in its software engineering group. Lean concepts such as modular reuse and Scrum[ix] had been used.

3.5.4 The Human Factor

Respect for Employees

The work environment was always very respectful. Fairness and respect in the Modern Management context was the order of the day. The working environment in Operations seemed amicable. Luncheons and celebrations occurred on a regular basis. Some community programs exist such as an affiliation with the United Way. A *spot awards* program had been in place for several years. Unfortunately, this program was removed as part of a corporate alignment process. To date, I am not aware of a similar program established to replace it.

Workforce Engagement

A successful suggestion program existed that was broadly based and included monetary awards and an end of year banquet for ideas that improved process, morale, safety, or costs. This appealed to the manufacturing employees who were the overwhelming bulk

of participation. Over the course of three years the program yielded a verifiable $1,000,000 in savings primarily through small improvements suggested and implemented in manufacturing (Brown, 2009). The total investment for the program was less than $100,000 over that time, giving a 10 to 1 return on investment. Unfortunately, the program was shut down in the corporate alignment. Another program was put in its place, but encouraged primarily *innovation* or ideas that directly pertained to new business ventures. While innovation is an excellent goal, it was a different program categorically. For instance, it did not have any monetary awards associated with it. Prestige and recognition were the motivation. Further, there was not an adequate category for the many small ideas that manufacturing had been generating. Engineers, managers and developers would most likely participate while employees in manufacturing would not. The final ruling here is that workforce engagement was considered but program execution was not optimized across the total cross section of employees. Engagement in the Lean sense through local team kaizens and problem solving was not a standard part of the business.

Hiring and Firing to Preserve the Lean Initiative

Key to bringing on the right Lean thinking individuals and eliminating the *anchor draggers* is an ability to know the difference. As the paradigm of senior leadership was not anchored in Lean there was no impetus to preserve it through human resource management. The director who initiated the 2008 Lean Summit was tapped to move into the leadership role of the Lean Product Development team, but this was not even a permanent or full time role. The team consisted of members who were asked but not forced to provide 20% to 50% of their time towards this team. The team facilitator was the only individual who was essentially full time on the team. In this environment, hiring and firing with a Lean motivation was not considered.

3.6 Company A Results

As of the date of publishing statistical results are not available due to delays and the ability for the team to make a substantive impact on the existing programs. The root

issue is that the right steps were not taken early in contrast to the other companies reviewed here. While there was a core group of well meaning and enthusiastic individuals, several key components found in the other company's successful transitions were lacking:

1. An absence of deep understanding of Lean principles was pervasive in leadership and even on the transformation team.
2. In contrast to the other three case studies, the leadership did not have the mindset of a radical Lean transformation.
3. Because leadership did not appear to embrace the *kaikaku*, program managers may have been tentative or unwilling to participate in the processes and lean tools recommended by the team because it had the possibility of near term negative impact.

3.7 IEC, Inc.[x]

IEC is a provider of highly reliable electronics to major Original Equipment Manufacturers (OEMs) and prime contractors to the US government. IEC was founded in 1966 and by the mid 1990's had plants in 5 global sites, over 2000 employees, and annual revenues in excess of a quarter billion dollars. The manufacturing model was high volume, low mix. It was mostly comprised of one product – mother boards for Compaq computers produced in that era. After a major downturn, IEC recreated itself through a Lean transition and now serves the defense, aerospace, industrial, and medical markets. Its niche is low volume, high mix, high complexity, high reliability, manufacture of complex circuit cards, system level assemblies, cable and wire harness assemblies, and sheet metal.

IEC has recently received the prestigious Award for Manufacturing Excellence through successful implementation of Lean Principles supported by metrics in growth, quality, and cost reduction. Jim Womack himself toured their facility in Newark, New York on one of his well known *Gemba Walks* (Biuso, Interview with Process Improvement Manager, IEC, 2011).

3.7.1 The Crisis Factor

In 1996 the founder and CEO passed away. The company subsequently struggled with lack of a solid strategy and leadership for the next eight years as customers left due to poor execution and pursued off-shore cost savings initiatives. As shown in Table 5, the revenue decreased from its peak of about $250 million to its low point of $19 million in 2005 and in the process all of the sites were sold off with the exception of the Newark, NY site.

Table 5: Falling IEC Revenue

	FY00	FY01	FY02	FY03	FY04	FY05
Sales Revenue (millions)	$204	$161	$39	$48	$28	$19

3.7.2 The Management Factor

Modern vs. Lean Leadership

IEC has taken great strides to standardize work. In the management approach, standardized work is embedded in their quality system. Best practices are captured, defined, and incorporated into the quality system and management dashboard. Management dashboards are constantly evolving as continuous improvement is applied. Senior leaders practice *genchi genbutsu* meeting with multiple small groups on a standard basis. These meetings follow standard agendas where feedback is carefully transformed into future actions.

Vision – Aligning Everyone's Motives

Initially, Don Doody, brought on to initiate the Lean transformation, provided a clear strategy for the company that included Lean Six-Sigma initiatives using presentations and clear documentation provided to the employees. Soon after, the IEC executive team incorporated policy deployment process which included a *radar chart* mapped to an *X-Matrix*. The radar chart provides a graphical image to communicate the vision to both the senior staff and every employee. These broad concepts are then targeted in measureable and defined goals on the X-Matrix chart. The X-Matrix connects

corporate strategic initiatives to site and departmental goals. Under each subcategory, specific leaders are listed with clear connection and responsibility to each delineated goal. This process effectively connects high level goals and vision to specific responsibility holders, usually mid-level managers and supervisors (Figure 8) The plan is updated every year and correlated to corporate goals as well as goals for each business area and even down to each individual.

The Lean Conversion - Radical Change then Incremental Change

Kaikaku was implemented to turn the company around initially when all but one of the five business units were sold off and the company was *right-sized* to allow for stable business and steady growth from 2005 forward. A total commitment to Lean thinking was introduced in methods very similar to those found at Wiremold and P&W. Subsequently, IEC has focused its workforce on continuous improvement activities through *automated problem solving* methodologies and tools with a manufacturing execution system (MES) developed internally by IEC. Visibility into the value stream is facilitated through instant information on quality, yield, cycle time, process capability, SPC, return rates and more. IEC also uses the Define, Measure, Analyze, Improve, and Control cycle (DMAIC) to facilitate continuous improvement (Figure 9).

Change Agent

The focus came from top management. The Executive Vice President of Operations, Don Doody, a Master Black Belt and Supplier Quality Engineer, was brought on in 2004 to train and coordinate the Lean transformation. His experience at GE achieving Lean-Six Sigma Black Belt provided the foundation needed to be a change agent. The Process Improvement Manager, John Biuso, helped to oversee and implement IEC's continuous improvement culture. Biuso trained under several senseis, one of whom was Chihiro Nakao who assisted P&W in their Lean transition. A deep understanding of Lean principles was shared by the leadership team and promoted vigorously through direct leadership involvement and vigorous implementation of Lean tools and training.

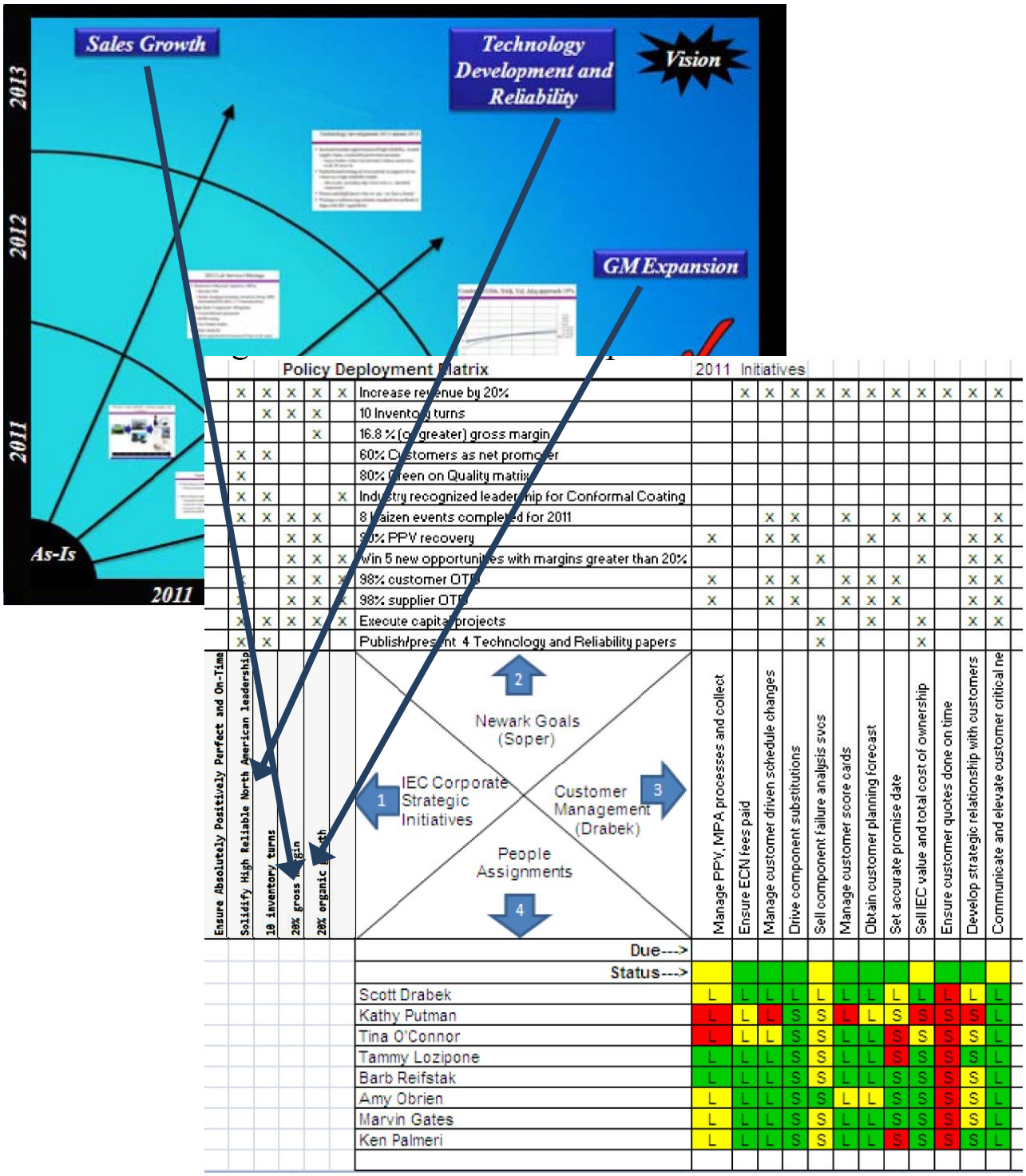

Figure 8: Policy Deployment via Radar Chart and X-Matrix

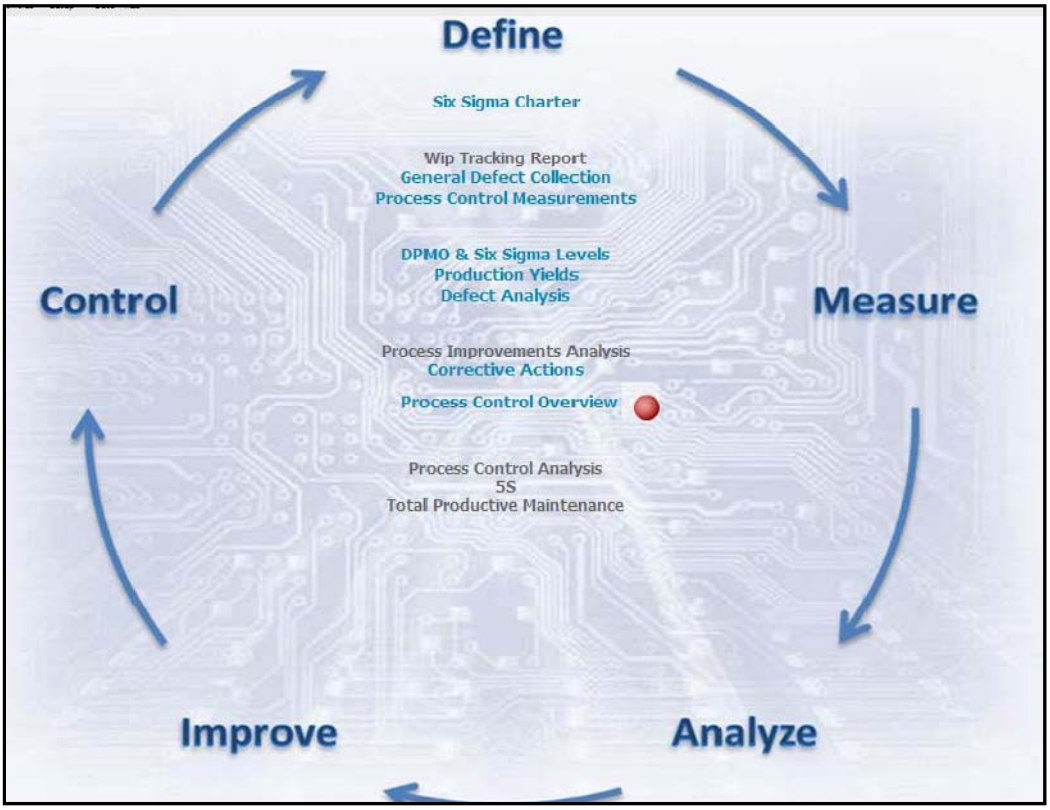

Figure 9: IEC's DMAIC Process for Continuous Improvement

Tenacity through the Conversion

The leadership within IEC firmly established the Lean enterprise after the right sizing event and held to their commitment to continually pursue application of Lean philosophy.

Focus on the Value Stream

IEC uses value stream mapping and focus factories and has implemented flow in production and in development. Managers also make use of dashboards that provide a quick look at pertinent up-to-date metrics across the business.

Sustainment

IEC has risen from near collapse in 2005 to nearly 20% growth year over year. By virtue of the recent AME Manufacturing Excellence Award and numerous examples of

properly implemented Lean tools, IEC has successfully been able to sustain gains. IEC admits that entropy is a powerful force and to sustain and improve simply takes continued focused effort. The way to do this, according to Biuso, is to:

> *Embed principles in your thought processes and language so it becomes part of your DNA.*

3.7.3 The Technical Factors

Core Technical Knowledge

IEC has 40 years of industrial experience in manufacture of high-end, high reliability electronics. IEC's niche is well understood and the company is on par with respect to capabilities. IEC's record of providing a quality product is excellent.

Understanding and Use of Lean Tools

IEC could well be placed alongside P&W in the 3rd edition of Lean Thinking with all the hallmark signs of deep understanding of Lean principles. These evidences include application across the three factors including employee engagement, execution of numerous Lean tools, consistent positive results, and evidence of monitoring and continuously improving processes. A list of common Lean tools used by IEC includes:

- Metrics to track process improvement
- Cyclical continuous improvement processes (P-D-C-A/ DMAIC)
- Standardized Processes
- 5-S
- *Kaizens*
- Value stream mapping
- Elimination of *muda* (waste), *mura* (variation), and *muri* (overburden)

3.7.4 The Human Factor

Respect for Employees

IEC strives to foster a learning organization. Multiple venues are offered for employees to build their capability, apply their skills, and assume more responsibility. IEC firmly believes everyone should maintain their life-long journey to learning and growing. This is evidenced by extensive training, and training for project teams including

DMAIC. Associates are taught skills to improve business and manufacturing processes and therefore help to solve the customers' problems.

In regards to maintaining and improving employee morale and health, IEC employs a variety of rewards and recognition to individuals and teams contributing to improvement. From gift cards to celebration lunches to appreciation directly from a manager, IEC puts a high value on making the workplace a fun and rewarding environment with many employee reward programs and community involvement.

Workforce Engagement

In regards to engaging the workforce in problem solving and continuous improvement activity IEC has automated problem solving methodologies and tools in an internally developed manufacturing execution system (MES). Information regarding quality, yield, cycle time, process capability, SPC, return rates, and other information, can be instantaneously obtained and analyzed to quickly and effectively solve problems using real time data. The MES also helps IEC to ensure standard work.

IEC goes further by joining or facilitating professional and technical conferences, membership in professional affiliations, networking and partnering with customers and suppliers. From these interactions, IEC implements organizational changes and improvements. Examples of organizational development include creation of Technical Users Groups (TUG's), Supplier materials network (industry *watch*) team, New Product Introduction (NPI) team structure, and refinement of shop floor metrics.

Hiring and Firing to Preserve Lean Initiative

The conversion team did not have to fire anyone because of strong contrary opinion. Many employees were enthusiastic and the majority coalesced. It was challenging to convince many that these methods would work, but the team was persistent in their training and work with the employees.

3.8 IEC Results

The results for IEC have been a complete turnaround in their business and future. The impact of successfully implementing Lean and Six Sigma practices can be described as stunning. Table 6 shows improvements directly attributed to Lean initiatives from 2005 forward. This is the result of the steady training and *genchi genbutsu* of the leaders at IEC and by successfully growing along the map of Lean Thinking.

Table 6: IEC Reported Lean Efficiency and Cost Improvements

	2005	2011
Inventory turns	2	9
WIP Factory Mfg. Leadtime (FML)	28	14
Walking Distance (ft) – Shipping	188	87
Walking Distance (ft) – Incoming Inspection	240	20
Inventory turns per day	2	9
WIP Factory Mfg. Leadtime (FML)	28	14
Batch Sizes (indexed to 2005)	100%	50%
Manufacturing Cycle Time (indexed to 2005)	100%	35%
Areas Using Min Acceptable 5-S (3 of 5)	0%	96%

3.9 Case Study Summary

Tables 7 and 8 below summarize the attributes of each company in the case studies above. For each category the chart provides a colored assessment that reflects the qualitative and relative level of accomplishment for that category. A legend is provided below for color selection. A quick visual assessment will provide an indication as to why Company A may have been unsuccessful thus far in their efforts towards Lean.

Table 7: Summary of Lean Attributes, Secondary Sources

	Crisis Factor	Management							Technical Factor			Human Factor	
		Lean Leadership	**Vision – Aligning Everyone's Motives**	**Radical Change then Incremental Change**	**Change Agent**	**Tenacity through the Conversion**	**Focus on the Value Stream**	**Sustainment**	**Core Technical Knowledge**	**Deep Understanding and Use of Lean**	**Respect for Employees**	**Workforce Engagement**	**Hiring and Firing to Preserve Lean Initiative**
Toyota (Benchmark)	WW II and 1950's Postwar Economy, Yes	Inventor and sustainer of Lean Principles, Excellent	Demonstrated by significant event of Kiichiro Toyoda stepping down for company's benefit, Excellent	Took radical steps in the 1950's to develop the Toyota Way and TPS Kaizen improvement continuously after Excellent	Kiichiro Toyoda, Eiji Toyoda, Taiichi Ohno, three of many, Excellent	Emerged from post WWII economy successfully, Excellent	Progenitor of concept, Excellent	Some quality miss steps in 2009-2011 timeframe due to focus on growth and less focus on training new recruits, Good	Toyota's cars are benchmark for quality and reliability, Excellent	Toyota is the original developer of Lean Toyota also has very deep understanding of Lean as creators of the system of thought, Excellent	Part of Deming's fundamental platform adopted by Toyota, Excellent	Key component in Toyota Way, Excellent	Kiichiro Toyoda cast himself on the sword to preserve the company. However, as growth became more central to vision, many employees did not have fundamental understanding of Lean (future study) Good
Wiremold Company	Revenue at break even, customers unhappy with missed shipments, and poor quality – Yes	With Art Byrne brought in, Lean Leadership was demonstrated continuously, Good	Clearly communicated with no recourse for going back, Good	Radical change during conversion, *kaizen* afterwards Excellent	Art was the one-man-band of change agents	Art had a history of tenacity – long term success at Wiremold proof.	Complete restructuring of manufacturing line, training across entire enterprise - Excellent	Excellent – until acquired by Legrand SA and Art retired. Lean now completely dismantled. Wiremold should not have agreed to the purchase	Industry leader in this technology. Good	Art Byrne brought deep understanding of Lean tools to Wiremold, Excellent	Increased profit sharing, better working environment Excellent	Good	No layoffs during the tenure of Art Byrne. (Legrand expected to lay off significant number of employees this year) Good
Pratt and Whitney	Engine orders dropped 80% over 3 years, quality and delivery schedules a mess – Yes	Mark Coran and Karl Krapek embodied Lean leadership, Excellent	Lower cost, increase quality., Good	Removal of 2.8 million sqft of mfg, all lines to continuous flow, drastically reduced supplier base Major right sizing requiring union negotiations	Shared across Karl Krapek, George David, Bob D'Amore, Good	Karl Krapek brought on specifically for his bull-dog presence and tenacity as well as Lean knowledge, Good	Customer Focus Factories set up just for this purpose, Excellent	Helped by consistent leadership. Excellent	Hands down one of the top engine makers in the world. Excellent	With the help of Karl Krapek and consultants, deep Lean knowledge was established, Good	Good	More-so than Unions wanted, was able to negotiate flex, multi-machine monitoring, etc., Good	In line with Lean principles

Table 8: Summary of Lean Attributes, Primary Sources

	Crisis Factor	Management							Technical Factor		Human Factor		
		Lean Leadership	Vision – Aligning Everyone's Motives	Radical Change then Incremental Change	Change Agent	Tenacity through the Conversion	Focus on Value Stream	Sustainment	Core Technical Knowledge	Deep Understanding and Use of Lean	Respect for Employees	Workforce Engagement	Hiring and Firing to benefit Lean
Company A	Business and outlook for federal budgets was poor. But not sure of level of crisis. Moderate	Pockets at best. Senior Leadership not engaged in Lean Thinking, Poor	Only vision was to save costs on Product Development. The target was 20% cost savings. Limited in scope, Poor	No radical changes considered. Incremental changes planned with roll out of hardware dev process Some kaizen activity, Poor	Lean team leader not given enough latitude by leadership and perhaps not right personality, Poor	Majority of Transition team did not stay on team to end, Poor	Not root cause issue, Fair	Not enough Information	Good technology and satisfied customers Good	Some Lean Six Sigma. Some understanding of DFM, very little implementation, Poor	Good	Attempts made here, but not comprehensive, Fair	Without Lean Thinking, this process is moot. Non-Existant
IEC	Complete restructuring was required and executed. The company was reduced to 1/5 the size quickly during right size.	Deep Lean understanding at high levels of the company, Excellent	Radar Chart, Tie in vision with goals down to individual employee, Excellent	Complete change in business with a no-holds-barred approach. Focused on continuous improvement Excellent	Good	With evidence in metrics, Excellent	Value Stream Managers, Focus Factories, Excellent	Actively engaging in Lean today and continuing to grow, Excellent	The product niche is well understood and well executed, Good	Textbook use of Lean thinking, Excellent	Well developed programs with many opportunities to show appreciation, Excellent	Many activities that reward employees monetarily as well as with community programs, Excellent	Though this is a tool that could have been used, employees generally coalesced, Good

Legend for Table 6 and Table 7

No Informati	Non-Existent	Poor	Fair	Good	Excellent

4 Conclusions and Recommendations

In this current worldwide economic crisis if business leaders take this opportunity to fully implement Lean principles across their organization and within the context of management, technical prowess, and with a human touch, the research presented here suggests that his or her company will benefit. Transitioning from mass production and traditional management methods to Lean has been shown to produce significant reduction in costs and time to produce while simultaneously improving quality and value for the customer. This occurs through rigorous and continuous focus on the right things such as elimination of waste, enabling visibility of the value stream for the customer, and improving flow of material and information through the factory. While this seems straightforward, the path to achieving these gains is less clear as demonstrated by many failed attempts at implementing these concepts successfully. The research above indicates that a radical and holistic application Lean philosophy across a total enterprise is the best approach.

4.1 Three Factors

Based on the success of three out of four companies studied, the best approach to Lean transition is with Lean leadership across a technically proficient work base with a view towards a respectful engagement of the employee towards problem solving at all levels.

Table 7 and Table 8 above give a visual assessment of the companies researched and their alignment with these fundamental factors. Wiremold and P&W both demonstrated success in there transitions as did IEC. Company A fell short on a majority of key elements shared across the other three companies.

4.2 Recommendation for Company A

Recommendation for Company Senior Leadership

My recommendation for Company A, or companies that are in a similar situation, is to follow the patterns laid out by those companies who have demonstrated success. The steps I would take are as follows:

1. Become equipped with the foundational knowledge of Lean through further study of the source material cited in this document.
2. Do the research to show the empirical benefits of Lean techniques in all pertinent areas of business including management, product development, and of course, production.
3. If you feel you need help and are not qualified to be a change agent, seek one out like Art Byrnes or Karl Krapek who have a successful record of creating significant improvements in their businesses through radical holistic application of Lean principles. This individual may be within the company already but may need to come from outside. Either way, the change agent need to already have the deep understanding of Lean.
4. Give this change agent substantial support in the form of authority, verbal and written backing, and participation and communication with the employee base.
5. Implement *kaikaku*, examining head count requirements, management personalities and reassigning or removing those that are unable to accommodate the change of process and thinking. This also includes introducing and implementing radically different processes that eliminate waste and increase quality. For instance, recall that flow and *heijunka* work together to improve quality. The companies I researched usually start in manufacturing but continue the process company wide.
6. Announce a clear, simple, and specific goal for this initiative company wide, why it is required, and how every employee will be a part. Communicate it regularly.
7. Communicate clearly that no employee will be laid off due to improvements generated from the Lean initiative. This should be sustainable if your initial *right sizing* activity was based on proper planning and good numbers and thorough execution on the plan.
8. Engage the employees through training and rewards programs and show them how to become problem solvers through Lean.
9. Create simple and measurable metrics to record progress; display measures prominently.
10. Continue the course with *kaizen* at every level, allowing the work teams themselves to conduct *kaizen* in their own areas indefinitely in pursuit of perfection.

Recommendation for Mid-level Company Leadership

Mid level managers are in a different situation than company leaders and should proceed down a slightly different course. My recommendation for mid-level managers within Company A is as follows:

1. Become equipped with the foundational knowledge of Lean through further study of the source material sited in this document.
2. Do the research to show the empirical benefits of Lean techniques in all pertinent areas of business including management, product development, and of course, production.
3. Create a business case with pro-forma numbers that demonstrate the financial issues and the impact that Lean has been shown to provide (use similar companies from like industries)
4. Locate seasoned Change Agents who would be willing to give a lecture or provide a tour of a truly Lean facility
5. State the case before senior management with a plan of action and a clear description of the level of change suggested and why.
6. At this point, if still unsuccessful, try again! Keep track of your efforts and what seemed most beneficial as well as what did not work. If your presentation did not speak to the specific customer value (your CEO's specific goals for business success), change it. This is *kaizen*.
7. A parallel effort is to apply Lean principles to the areas that you do have sway over. Execute with all three factors and take careful metrics. You should see much more quickly in an isolated case. Use these metrics in your business case.
8. Once the company leadership is convinced, see *Recommendation for Company Senior Leadership* above.

Once success is achieved the Lean leader must take care not to rest on past achievement. Recall sustainment is fragile. Rather, he or she must keep everyone's eyes steadily on the

vision of the business and how it creates value for the customer while constantly and vigorously seeking out and eliminating waste.

4.3 Additional Research

Actual data was difficult to obtain in some cases due to the proprietary nature. Providing more numeric data to concisely demonstrate improvements in quality, drop in lead times, reduction in costs, and improvement in customer satisfaction would be desirable.

Further, Toyota has been the leader head and shoulders over competition in consistent quality, even within Japan. In light of the recent rash of recalls and quality issues it appears that something happened to get even the mighty Toyota shifted from their core values. Interesting further study may include what happened at Toyota that lead to this current state and how Toyota is dealing with it.

Finally, the latest push in Lean philosophy is to apply its basic principles to company management, the health industry, and even government (Corell, 2004). If the basic tenants of Lean, focus on customer (the citizens), vigorous elimination of waste (unnecessary spending on fruitless programs), and pursuit of perfection, could be fully implemented in the federal government this nation could be strengthened greatly and the breadth of positive impacts is difficult to imagine.

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[i] "5 Why's" is a process where, after the initial question is answered, continue at least four more times in order to drill down to the root cause.

[ii] Just In Time (JIT) is a process that allows for significantly reduced in-process inventory and allows a company to be more nimble in the variety of product, which adds value, and the speed in which the product flows through the production process. When done right, JIT delivers the right product to the right place at the right time to meet specific customer needs and wants (Liker, 2004).

[iii] Dr. Kyle Lewis, Engineering Management Program, ENM 380.1 Managing People and Processes, The University of Texas at Austin, 2010.

[iv] The primary source for the Wiremold case study can be found in Lean Thinking (Womack, Jones, 1996). All other sources are cited within the case study.

[v]The primary source for the Pratt & Whitney case study can be found in Lean Thinking (Womack, Jones, 1996). All other sources are cited within the case study.

[vi] A Material Review Board, or MRB, is usually a panel of quality assurance, operations engineering, and hardware development engineering that review defects found on product from the manufacturing line and determine if the product may be shipped to the customer as "conforming to standards". Often approval is given after a specified rework activity is accomplished.

[vii] The P&W Core Values logo can be found at http://www.pw.utc.com/about_us/company_values.asp

[viii] Information for the Company A case study came from first hand observations and discussions with numerous employees from 2008 through 2011.

[ix] Scrum, a word borrowed from rugby, means is an iterative, incremental framework for project management often seen in agile software development, a type of software engineering (Sutherland, 2004 and 2010).

[x] All information for the IEC case study was provided by interviews with John Biuso and a 2011 AME Manufacturing Excellence Award Application (Biuso, 2011).